PEREGRINE
ENERGY GROUP

ANALYSIS OF JOB CREATION from 2015 Expenditures for Energy Efficiency in Rhode Island by National Grid

Prepared for National Grid

Prepared by:

Peregrine Energy Group, Inc.
2 Oliver Street
Boston, Massachusetts 02109

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Executive Summary

Electric and gas energy efficiency programs and services sponsored, supported, and provided by National Grid in Rhode Island are intended to help eliminate unnecessary energy use, save money for customers, improve the environment, and increase the health, comfort, and safety of homes and businesses.

In 2015, National Grid spent a total of $103,026,953 on electric and gas energy efficiency programs and services in Rhode Island and saved 222,822 MWh and 419,778 MMBtu.

The focus of this study is less *what* was done by National Grid programs than *how* it was done and by whom. Successful delivery of the 2015 energy efficiency programs to National Grid's customers includes active involvement of a broad range of workers across a wide array of businesses, including not-for-profits, contractors, plumbers, rebate processors, state agencies, engineering firms, marketing firms, and others.

In order to quantify the number of direct workers involved, National Grid commissioned Peregrine Energy Group, Inc. ("Peregrine") to conduct a study of the job impacts of National Grid's energy efficiency programs delivered to Rhode Island electricity and natural gas customers in 2015. Peregrine conducted a like study for National Grid in Rhode Island in 2014 and 2013.

Peregrine determined that 695.8 full-time equivalent (FTE) workers were employed in 2015 as a result of National Grid expenditures for energy efficiency programs provided to its Rhode Island electricity and natural gas customers.   Most of the jobs created as a result of energy efficiency investments were local because they were tied to installation of equipment and other materials. One FTE equals 1,760 work hours, or the total of one person working 8 hours a day for 220 work days in an average year. Because a "full-time equivalent" employee often represents the labors of more than one person over the course of a year, the number of individual workers employed as result of Rhode Island energy efficiency programs funded by National Grid is far larger that the total of FTEs.

The 2015 FTE total was 5% greater than the 666.1 FTE workers that Peregrine had attributed to National Grid's Rhode Island energy efficiency program investments in 2014 and 25% greater than the 558.9 FTEs in 2013[1]. National Grid's programs and delivery strategies were

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[1] 2013 and 2014 FTE counts have been updated this year for consistency purposes due to changes in methodology used in 2015 to calculate FTE jobs associated with installation of weatherization measures in multifamily and commercial buildings. These changes are described in more detail in Attachment A on page 39.

substantively the same in 2015 as they had been in the prior two years. However, 2015 was characterized by a continuing increase in customer participation, demand, and acceptance of energy efficiency services. Further, price drops for and growing adoption of more energy efficient, longer-lasting, and increasingly diverse LED (light emitting diode) lighting products, created installation opportunities and program participation by an increasing number of businesses.

The study identified 1,009 companies and agencies involved in National Grid's Rhode Island programs, 79% of which were located in Rhode Island. The companies identified include those whose employees installed energy efficiency measures, as well as companies who assisted customers to secure equipment rebates, for example through New Construction, High Efficiency HVAC, and Upstream Lighting programs. These findings for 2015 once again confirm that job creation is an additional significant benefit that National Grid's investment in energy efficiency contributes to Rhode Island's economy overall and directly to the business owners and their employees that participate in and deliver these programs and services.

Workers supported by these programs were employed by a broad range of companies and organizations involved in energy program design, management and delivery. In addition to National Grid staff, participating employers included program design consultants, energy program management specialists, marketing and advertising specialists, equipment manufacturers and suppliers, equipment and appliance retailers, architectural firms and developers, engineers and energy analysts, installation companies and independent contractors, quality assurance inspection companies, utility rebate processing houses, waste material recyclers, and program evaluators. In addition, Community Action Program agencies under contract to the state Department of Human Services delivered low-income energy efficiency services for the federal Weatherization Assistance Program (WAP). A full list of companies involved in the 2015 Rhode Island energy efficiency programs is provided at the end of this report.

Introduction

National Grid's Rhode Island energy efficiency programs focus on delivering cost-effective energy savings to residential customers, low-income residential customers, small and large commercial businesses, and industrial customers. In 2015, National Grid spent a total of $103,026,953 on electric and gas energy efficiency programs in Rhode Island created 222,822 MWh in annual electricity savings saved 419,778 MMBtu in annual gas savings. It is important to note that this funding does not include the customer share of installation costs and other leveraged funding such as Regional Greenhouse Gas Initiative (RGGI) and the Low Income Heating Assistance Program (LIHEAP).

For the third year in a row, National Grid commissioned Peregrine Energy Group, Inc. ("Peregrine") to conduct a study of the job impacts of National Grid's energy efficiency programs and services delivered to Rhode Island electricity and natural gas customers in 2015. The objective of the research was to count or estimate the number of direct jobs attributable to National Grid's 2015 energy efficiency programs. While job creation is not a formal goal of National Grid's energy efficiency programs and services, this study illustrates the additional economic benefits that investments in energy efficiency contribute to Rhode Island and to the businesses participating in National Grid's programs. This study meets the requirements of General Law 39-2-1.2, enacted by the Rhode Island General Assembly in 2012.

An additional objective of the 2015 study has been to attempt to identify and explain year-to-year changes in job impacts attributable to National Grid investments, comparing 2015 to previous years' results. Each annual study has endeavored to find and count the full-time equivalent (FTE) employees engaged in all aspects of National Grid's energy efficiency programs. Peregrine has assumed that one FTE, regardless of job type or responsibilities, equals 1760 work hours, or the equivalent of one person working 8 hours a day for 220 work days in an average year.

Unlike the energy savings resulting from these programs that are predicted, analyzed, measured, and recorded, job impacts of energy efficiency improvements are identified, if they are counted at all, as an expense. Types of employees and number of hours worked to deliver programs and services are not captured, except by employers themselves for payroll and business planning purposes. For this reason, calculating job impacts can be more art than science.

As has been the case with prior years' studies, this year's study findings were developed through interviews with managers at energy services companies, equipment vendors, and contractors identified by National Grid for Peregrine or identified as sub-contractors by companies that Peregrine interviewed. These companies voluntarily shared information on how they staff their contracts and services and even researched payroll records to provide FTE counts. Where possible, the study cites the companies that provided information to Peregrine.

Peregrine also completed a detailed review of National Grid's records of all energy efficiency measures installed in homes, apartment buildings, businesses and industrial facilities throughout Rhode Island in 2015. Peregrine then calculated typical labor hours required for each installed energy savings measure, based on industry standards and discussions with the contractors themselves and other experts, and extrapolated total FTE employment using total counts of measures installed in 2015 that were reported to and by National Grid.

The report is divided into four primary sections:

1. An Efficiency Workforce Overview that describes the types of companies and workers engaged in providing efficiency program-related services and support in Rhode Island
2. The Delivery Approach used for individual programs
3. Summary Counts of FTEs with observations on their significance
4. Attachments describing Peregrine's methodology in more detail, providing Peregrine's interview guide, and listing specific companies that supplied the workforce.

Efficiency Workforce Overview

Peregrine recognizes two main categories of employers/employees that participate in the delivery of National Grid's energy efficiency programs. These categories are:

- "Program Support Service Providers" that are employers and employees involved in program planning / administration, marketing, rebate processing, and evaluation and market research.
- "Direct Service Providers" who are responsible for sales, technical assistance and training, and for supplying and installing approved efficiency measures that National Grid promotes and encourages with incentives and rebates.

Program Support Service Providers

The Program Support Services category includes:

- Companies engaged to provide marketing, outreach, public information, and other related support services, including media placement and design of collateral marketing materials;
- Specialized firms processing and paying out rebates offered for purchase and installation of install high efficiency equipment; and

- Evaluators of the overall performance of and savings associated with the National Grid programs.

National Grid Employees

National Grid staff engaged in energy efficiency program design, regulatory matters, administrative management of contractors, marketing, and evaluation are included in the Program Support Services category. Information provided by National Grid identified 85,204 person-hours of time associated with Rhode Island energy efficiency program activities, equal to 41.6 FTEs. Peregrine is reporting all National Grid FTEs as a separate category for purposes of this study and not allocating them to specific programs or groups of programs.

Support Services Contractors

Peregrine interviewed the majority of lead vendors who supported National Grid in these activities to obtain information on their roles and responsibilities in program delivery and FTE counts. Often, these FTEs represented the aggregation of small numbers of hours by many employees. In some instances, this was because a contractor's role may have been limited in duration and/or required contributions from a multi-disciplinary team. In other instances, it was because a team with multi-disciplinary capabilities was, for reasons of cost effectiveness, providing services to National Grid in Rhode Island and other states or to National Grid and other utility companies.

Depending on the nature of the services the vendor provided and whether the support provided could be associated with specific programs, contractor time was allocated according to the overall allocation of gas and electric spend by program sector (Residential, Income Eligible Residential, Commercial and Industrial), or allocated to a specific program sector.

Program Planners and Administrators

Vermont Energy Investment Corporation (VEIC) and its subcontractors Optimal Energy and Energy Futures Group continued to serve as consultants to Rhode Island's Energy Efficiency and Resource Management Council (EERMC) in 2015. Optimal Energy primarily provided services out of offices in Providence, Rhode Island. The VEIC team of market sector specialists assisted with planning, provided guidance for spending of Regional Greenhouse Gas Initiative ("RGGI") funds for efficiency, and helped with oversight of programs offered by National Grid. The nine staff associated with the three organizations that provided these direct services billed approximately 2.5 FTEs of time. These services were paid for out of system benefits charges and the energy efficiency budget.

Marketers

National Grid's energy efficiency marketing spend for Rhode Island in 2015 was just over $4,000,000, equal to just under 4% of the total Rhode Island energy efficiency expenditure. National Grid had eight firms engaged in a variety of marketing roles designed to increase general efficiency awareness, target specific customer segments and sub-segments for programs and services, and engage and promote trade allies. Much of the budget spend was used for media message placement, printing and direct mailing, and electronic communications.

Kelliher Samets Volk (KSV), a Vermont-based regional marketing firm specializing in the utility sector, was National Grid's primary marketing consultant in 2015, organizing brand marketing campaigns to generate awareness among customers about the breadth of National Grid's energy efficiency programs, campaigns directed at trade allies, and targeted market sector campaigns that focused on specific programs. In addition to coordinating all the efforts of other specialized marketing firms supporting National Grid, KSV's role included media placement, web-based initiatives, organizing social media campaigns, and organizing phone messaging. As KSV's Ashley Nichols described it, the marketing team's goal was "the marriage of awareness and hyper-targeting." They analyzed and reported to National Grid monthly on leads generation for each market segment, monthly marketing activities by different parties, and going forward marketing efforts planned.

KSV identified 40 individuals at the firm that touched the National Grid Rhode Island account in one way or another. Ten of this number accounted for 80% of the total 5,200 hours KSV billed to Rhode Island in 2015, down from 5,900 in 2014 ("We were more efficient in 2015."[2]). Total 2015 hours equaled 3 FTEs. Staff included a three quarter (0.75 FTE) time brand manager based in Little Compton, Rhode Island supporting National Grid.

Additional marketing firms supporting National Grid in Rhode Island in 2015 included Questline Inc., Ideas Agency Inc., Integrated Marketing Services, and InnerWorkings, Inc., Impressions ABA, Sacks Exhibits, and RAM Marketing.

Marketing FTEs are allocated across all programs.

Rebate Processors

National Grid contacted with Blackhawk Engagement Solutions (BES), formerly Parago, in 2015 to process rebates offered for a variety of energy efficient products. BES also supports other clients nationwide. BES scanned, data-entered, and validated rebate applications, processed

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[2] Interview with Ashley Nichols, KSV

payments, and cut and mailed checks. All told, BES required 1.72 FTEs, equal to just over 3,000 hours, for rebate application scanning, data entry, customer service, quality assurance, processing services, reward fulfillment, account management, and technology support.

Evaluators

The total Evaluation and Market Research expenditure for Rhode Island for 2015 was $785,213, paid for out of energy efficiency program funds. Contracted firms specializing in utility program evaluation included DNVGL, Opinion Dynamics, Cadmus Energy Services, Illume Advising, and others. Generally, outside evaluator time was attributed to specific programs and the FTEs associated with those hours added to program totals. Peregrine calculated that 3.65 FTEs of labor were associated with evaluation activity in 2015.

Direct Service Providers

The Direct Service category is comprised of contractors hired by National Grid to deliver and promote Rhode Island energy efficiency programs, specialized technical support providers, and suppliers and installers of energy saving equipment.

This category included, but was not limited to:

- **National Grid account managers** providing outreach and direct technical assistance to customers, particularly for large commercial and industrial retrofits, and new construction[3];
- **Energy services companies specializing in field services and installation program management** who were engaged by National Grid to deliver programs, providing schedulers, technical specialists, engineers, installers and trades people, managers and supervisors, warehouse materials handlers, quality assurance inspectors, bookkeepers, and data entry staff;
- **Energy services companies** hired by National Grid to engage, support, manage, and coordinate product suppliers and distributors, retail store offerings, and service networks;
- **Electrical and mechanical engineers** employed by contracted consulting firms and dispatched to identify potential projects, quantify savings, and recommend actions that customers should take;

[3] As noted above in the National Grid description under Program Support Services, all National Grid FTEs are reported together in a separate category for purposes of this study and not allocated to specific programs or groups of programs.

- **Equipment suppliers** providing energy efficient equipment and approved materials directly to National Grid customers or to installation contractors.

- **Independent contractors** installing energy efficient equipment and approved materials for National Grid customers in one or more market sectors, often as subcontractors to National Grid-designated Program leads, but also, increasingly, as self-directed installation vendors.

- **Quality assurance inspectors** that were engaged independently of service delivery contractors to check a sample of completed work to ensure that program standards were being met and that projected savings would likely be realized.

The role and contributions of Direct Service Providers is described in detail in the next section.

Energy Efficiency Program Delivery

National Grid's energy efficiency program delivery strategy in 2015 varied for different market sectors and sub-sectors, based on fuel type, customer rate class, end-use technology, and whether the objective was to affect energy efficiency of current operations or to reduce energy use in new construction. While this strategy remained relatively constant from 2014 to 2015, certain programs changed somewhat in response to emerging technology and market opportunities. This section describes how National Grid delivered specific electric and gas energy efficiency programs and services in 2015 and by whom.

Residential Programs

In 2015, National Grid's residential programs offered a range of services and incentives, from home energy audits with installation of low-cost materials to full weatherization services and heating system replacement to rebates and market channels for purchases of high efficiency appliances and lighting. These programs were designed to reduce energy use by electric and gas customers living in single-family dwellings, 2 to 4 unit buildings, and larger multi-family residences of 5 to 20 units and 20 units or greater.

National Grid's residential programs were delivered primarily by contractors that specialized in supporting utility energy efficiency programs. The contractors' role was to educate a range of market players, buyers and sellers, and bring them in line with National Grid's energy efficiency objectives through education, training, and technical support. Information on each program's delivery mechanism is detailed below.

In 2015, the installation of residential energy efficiency measures again increased compared to previous years, reflecting increased levels of participation by customers. These increases in spending and installations also resulted in increases in jobs associated with program and service delivery.

EnergyWise Single Family (gas and electric)

In 2015, EnergyWise offered customers living in single-family homes (defined as 1 to 4-unit buildings) a comprehensive energy assessment of their energy use, with building-specific recommendations for actions to take to improve the energy efficiency of their homes.

- Participants in this program received recommendations, technical assistance, and financial assistance to improve building insulation and replace inefficient lighting fixtures, appliances, and thermostats with high efficiency models.
- As part of the energy assessment, field staff installed energy efficient lighting, low-flow showerheads, faucet aerators and smart power strips.
- They also wrote work orders for weatherization services (insulation and air sealing) by insulation contractors and for new high efficiency heating and hot water system installations by plumbing and heating contractors, if warranted.
- After the installation of insulation and heating equipment, quality assurance inspections were provided to confirm that equipment was installed properly.
- The program continued to offer the Rhode Island Heat Loan, which provides 0% interest financing to eligible single-family customers to support the adoption of recommendations made during the assessment. Customers who live in one to four unit single-family residences are eligible for a 0% interest loan of a minimum of $500 up to $25,000 with terms up to seven years.

Delivery:

For 2015, National Grid again contracted with RISE Engineering, based in Cranston, Rhode Island, to manage and deliver the EnergyWise Single Family program. RISE employees, totaling nearly 60 FTEs, involved in program delivery included program managers, office and field staff supervisors, field auditors, field installers and technicians, field inspectors, intake staff and schedulers, warehouse and material management staff, electricians, quality assurance / quality control inspectors, and accounting and contract oversight personnel. In response to increased customer participation in 2015, RISE added field auditors, field technicians, and inspectors to their staff in the course of the year. Field staff completed 10,055 energy audits in 1-4 unit buildings in 2015, up from 8,654 home energy audits in 2014. Demand for services required that

RISE once again sub-contract with Ocean State Energy Audits[4] to perform single-family audits and related installation work, requiring an additional 3 FTEs in the field.

Work orders written by auditors resulted in 2,819[5] customers proceeding with weatherization services (i.e. insulation and air sealing). In 2015, 26 independent insulation contractors installed the insulation and air-sealing materials recommended by RISE. Insulation crews were led by a BPI-certified crew chief. RISE received a program management fee for its services for this program that included a fee per audit, a fee per item installed by RISE staff, and a percentage mark-up (i.e. cost plus) on insulation work completed by contractors.

Independent heating contractors installed high efficiency heating system components, again using work orders generated by field auditors. Almost 900 gas-fired systems and nearly 400 liquid fuel-fired systems (oil or propane) were installed as a result, as well as many new energy-efficient domestic hot water systems.

As part of EnergyWise Single Family, RISE helped customers to secure HEAT loans to finance the installation of more efficient heating systems, hot water systems, and insulation upgrades. There were 1,008 loans in 2015 through private lending institutions, providing financing for 673 weatherization jobs and 552 new high-efficiency heating systems[6].

CMC Energy Services, Inc., doing business as Competitive Resources, Inc. whom they acquired in 2014, provided quality assurance (QA) inspections of a sample of residential customers served[7]. QA addressed all phases of service delivery and included review of field auditors' performance, post-audit counts of installed measures, and post-weatherization site visits to confirm proper installation technique and customer satisfaction with results. Nine field inspectors conducted residential QA visits in Rhode Island and Massachusetts, supported by schedulers and data entry staff. Approximately 2.25 FTEs of this team were engaged in National Grid's residential programs in Rhode Island.

EnergyWise Multifamily (gas and electric)

In 2015, EnergyWise Multifamily continued to provide comprehensive energy services to multifamily customers in buildings with five or more units, including energy assessments, incentives for heating and domestic hot water systems, cooling equipment, lighting, and

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[4] Ocean State Energy Audits also provides audits for income-eligible National Grid customers on a sub-contracted basis for RI Community Action Agencies.

[5] Source: Peregrine interview with RISE Engineering

[6] Many additional heating systems were installed in 2015 for audit recipients who did not elect to finance their purchases through the HEAT program.

[7] Source: CMC Energy Services, DBA Competitive Resources Inc.

appliances. These same services were offered to both market rate and income-eligible multifamily properties. The programmatic approach for serving existing multifamily properties included using a designated primary point-of-contact to manage and coordinate services offered through the full portfolio of National Grid programs, including EnergyWise, Large Commercial Retrofit, Income Eligible Services (i.e. Low Income), and ENERGY STAR® HVAC.

Delivery:

RISE Engineering also managed the EnergyWise Multifamily Program for National Grid. RISE staff included a program manager, a technical services director, field coordinators, field auditors, warehouse materials handlers, electricians, and project intake and coordination staff. This same staff was responsible for the Income Eligible Multifamily Program described below. RISE had a combined 14 FTEs working on the EnergyWise and Income Eligible Multifamily programs[8].

RISE engagements in this sector resulted in 4,312 market rate units and 4,876 income eligible units[9] participating in the program in 2015, up from 3,400 market rate and 4,000 income eligible multifamily units[10] in 2014. Standard income units were in 57 apartment buildings and 67 condominium complexes.

RISE staff served as project managers for retrofit projects, meeting with building facility managers, making presentations to condominium boards and owners, and writing work orders and scopes of work (e.g. for air sealing, attic insulation, lighting fixtures, and even replacement refrigerators from retailers for low-income residents).

Independent contractors installed weatherization materials (insulation and air sealing) and heating equipment components. RISE pre-qualified the insulation contractors that bid on this work. This program was coordinated with the Commercial Multi-family program for gas heating systems. Plumbers and electricians were engaged as sub-contractors as needed.

As was the case with the EnergyWise Single Family program, National Grid engaged CMC Energy Services to perform independent quality assurance checks on multifamily services.

Residential New Construction (gas and electric)

This program promoted the construction of high-performing energy efficient single family, multifamily, and low-income homes in both 1 to 4 unit buildings and multifamily buildings up to

[8] Source: RISE Engineering
[9] Source: RISE Engineering
[10] Source: RISE Engineering

five stories. To that end, it educated builders, developers, housing agencies, tradesmen, designers, and code officials regarding the construction requirements, performance benefits, and costs for such buildings. Changes driven by the Residential New Construction program improve lifecycle energy performance. This is primarily attributable to better materials selection and improved construction methods. Builders say that the incremental cost of these enhancements are more than offset by faster home sales and fewer call backs to address owner concerns.

In 2013, the program had adopted a performance-based tier structure with corresponding financial incentives and began to capture savings from the Renovation/Rehabilitation and Deep Energy Retrofit offerings. This continued in 2014 and 2015, with additional incentives being offered, but with increases in performance verification as well. Incentives paid were based on the percentage of improvement over an established baseline.

Delivery:

For program year 2015, National Grid again contracted with Conservation Services Group (CSG), based in Westborough, Massachusetts, to deliver this program. 2015 was the 19th year CSG had managed the Residential New Construction program. In mid-year 2015, Conservation Services Group was acquired by CLEAResult, a rapidly growing national energy services provider.

Staff located at the Westborough office focused on program management, data management, and administrative responsibilities, while three field and training personnel were based in East Greenwich (Warwick), Rhode Island. Field personnel provided trainings and reviewed plans submitted by builders and developers. A continued emphasis has been to try to reach out to all Rhode Island builders to continue to expand the impacts of the program statewide.

CLEAResult also modeled proposed buildings and completed inspections that verified and certified that construction practices for participating buildings receiving performance ratings. In 2015, 442 units of housing and homes received HERS ratings[11]. 239 of the housing units rated were multifamily units. CLEAResult brought 54 new builders and developers into the Residential New Construction program in 2015, continuing National Grid's success with market transformation.

With approval from National Grid, Peregrine did not include labor hours for this program beyond the program implementation services provided by CLEAResult. While incentives offered by National Grid influence the installation of more efficient materials and products in a new home, such installations do not substantially increase the labor hours. The labor needed to

[11] Source: CLEAResult

construct a high-efficiency home is more or less the same as for buildings that meet current code requirements. In addition, these new homes would have been built anyway without the intervention and support of the program, even though they would not achieve the same standards for efficiency in their design and function. Therefore, no construction labor component is counted for purposes of this study.

Residential Codes and Standards Initiative

The Codes and Standards Initiative's goal has been to provide information and technical support to the construction / design community and to code officials in municipalities to increase code compliance and promote advanced and stretch codes like the Rhode Island Green Construction Code.

Delivery:

National Grid continued to contract with Conservation Services Group (CSG) in 2015, now CLEAResult, to lead this initiative in parallel with the Residential New Construction program. CLEAResult trainers conducted 14 residential classroom trainings and 15 on-site residential trainings[12]. In addition, trainers delivered 12 commercial classroom trainings and three on-site commercial trainings in 2015. They also had a circuit rider to provide on-site technical assistance as needed.

Residential Home Energy Report Program (gas and electric)

National Grid began offering Home Energy Reports (HER) statewide to all residential customers in April 2013 and continued the program through 2014 and 2015. The Rhode Island HER program, the first statewide behavior program in the country, uses historical energy usage benchmarking and social comparisons to encourage energy efficient behavior in the homes of residential customers. The program provides customers with access to personalized energy usage information and the ability to directly link with National Grid's other residential energy efficiency programs and services.

Delivery:

Opower, with offices in Arlington, Virginia, delivered the Rhode Island HER program, using proprietary behavioral analysis and energy audit software. Opower is staffed with behavioral scientists, marketing experts, engineers, and software product developers, with support staff, operating in cross-functional teams to develop and deliver these audit reports in Rhode Island and elsewhere across the U.S.

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[12] Source: CLEAResult

At the end of 2015, Opower had developed and distributed data-driven, software-generated reports to 268,263 residential electric and 130,455 residential gas National Grid customers enrolled in the Home Energy Report program in Rhode Island. The objective of these reports was to generate actual energy savings by providing “tips” for reducing energy use and to increase demand for and participation in other residential programs offered by National Grid. Comparing participants to a control group, Opower estimated that their reports result in a 10% – 20% lift in program participation[13]. Opower also created an online engagement platform, documenting savings and working with existing Company systems.

Residential Community Based Initiatives (gas and electric)

Rhode Island Energy Challenge is a collection of locally-based initiatives that leverage trusted community partnerships and develop targeted marketing strategies in order to promote National Grid’s residential (and commercial) energy efficiency programs in targeted communities. Community-based initiatives resemble political campaigns that are trying to get out the vote. They are run through communities as municipality-wide initiatives or as market-segment focused efforts, with the goal of increasing awareness of and participation in National Grid offerings and driving residential customers to make behavioral changes that reduce energy use.

Delivery:

Connecticut-based Smart Power coordinated the Rhode Island Energy Challenge, which encouraged communities to establish energy efficiency goals and take steps to achieve them. The program had a Rhode Island-based manager, supported by operations staff in Connecticut. At the community level, the program enlisted volunteers to promote participation, though these volunteers are not counted for purposes of this study. Major initiatives in 2015 targeted the cities of Providence, North Providence, and Central Falls. A new 2015 initiative in partnership with local community action agencies targeted renters in income eligible housing complexes. This behavioral program is continuing in 2016. A church-based initiative promoting “Energy Sundays” launched with Rhode Island Interfaith Power and Light in 2014 continued in 2015. A campaign directed at college students at Brown University, Johnson and Wales, University of Rhode Island, and Providence College was also kicked off in 2015.

ENERGY STAR® Lighting (electric)

ENERGY STAR® Lighting is a point-of-purchase initiative implemented jointly with other regional utilities. It provided discounts to customers for the purchase of ENERGY STAR® rated lamps and

[13] Source: Interview with OPower

fixtures and solid-state lighting through instant rebates and special promotions at retail stores. A mail-order catalog and online store were also available to customers for lighting purchasing. As noted earlier in this report, new LED lighting has become a significant piece of this program, increasingly displacing compact fluorescent lights that dominated screw-in incandescent lighting replacements in recent years.

Delivery:

Lockheed Martin Services, with an office in Marlborough, Massachusetts, again supported the residential consumer lighting initiative in 2015, providing direct outreach and education to both product retailers and manufacturers. Staffing in 2015 included a full-time Rhode Island-based field representative and a nearly full-time (90%) Rhode Island-based account representative to work with retailers statewide, providing product information, training them to upsell to more efficient products, offering staff events, conducting in-store surveys and point-of-sale promotions. Lockheed Martin again employed a School Fundraising Coordinator in 2015, while increasing the coordinator's time Rhode Island time from 18% to 50%, who helped organize school-based lighting product and power strip purchasing and distribution. Lockheed Martin reported that program sales volumes in 2015 were as good or better than in 2014

Massachusetts-based Energy Federation, Inc. provided a product catalogue and online store for National Grid and other regional utilities to promote and supply qualified products and to provide technical assistance to customers. This fulfillment function employed a manager, required a call center that took orders, and included warehouse personnel serving orders from Rhode Island customers, customers from elsewhere in New England, and nation-wide.

As outlined in the program description, ENERGY STAR® Lighting employed a number of avenues to encourage the purchase of energy efficient lighting to residential customers. Part of this region-wide initiative focused on retail outlets. However, retail outlet employees were not counted for this study since the sale of these products had no discernible incremental effect on store employment (i.e. it primarily resulted in different lighting choices by consumers).

ENERGY STAR® Appliances (electric)

In 2015, ENERGY STAR® Appliances was again run in collaboration with other regional utilities to promote the purchase of high efficiency household appliances, including kitchen appliances, and electronics. These appliances carry an ENERGY STAR® label. The program also offered refrigerator recycling, which helped address a significant barrier to purchasing a more efficient refrigerator, while removing non-efficient units from the market, recycling their components, and capturing and properly disposing of refrigerants.

Delivery:

As was the case with ENERGY STAR® Lighting, ENERGY STAR® Appliances was primarily a retail-store based initiative. And as was the case with ENERGY STAR® Lighting, retail outlet employees were not counted for this study since the sale of these products had no discernible incremental effect on store employment (i.e. it primarily resulted in different appliance choices by consumers). Again, as with ENERGY STAR® Lighting, Lockheed Martin Services engaged major retail outlets, providing the same support as for ENERGY STAR® Lighting.

National Grid and the other regional utilities contracted with JACO Environmental to recycle refrigerators as part of the holistic strategy to encourage the purchase of energy efficient refrigerators. JACO employed a regional facility in Franklin, Massachusetts for refrigerator collection, dismemberment, and recycling. JACO employed a local program manager to service the regional program, staffed a large warehouse in Franklin, and had staff dedicated to New England utility customers at its call center in Washington State.

ENERGY STAR® HVAC (gas and electric)

The High-Efficiency HVAC programs (*Gas Heat* [heating] and *CoolSmart* [cooling]) promoted the installation of high efficiency gas heating and electric cooling systems via tiered rebate levels for more efficient technologies including ductless mini-splits, heat pumps, heat pump water heaters, boilers, furnaces, Wi-Fi thermostats, boiler reset controls, and furnaces equipped with high efficiency fans. The program provided in-depth contractor training for design, installation, and testing of high efficiency systems. Furthermore, the program provided quality installation verification training, ensuring that all equipment is properly sized, installed, sealed, and performing.

Delivery:

National Grid hired Westborough, Massachusetts-based Conservation Services Group (CSG), now CLEAResult, to deliver this Program, which included three related initiatives: *Cool Smart*, the *Rhode Island Gas Heat Program*, and *Commercial Upstream Cooling*. Both *Cool Smart* and *Rhode Island Gas Heat Program* focused on contractors, with Conservation Services Group providing training, technical support, and marketing assistance to help encourage customers to upgrade to higher efficiency systems. *Cool Smart* also provided 732 quality control inspections in 2015, called Quality Installation Verifications or QIVs. 1,500 Cool Smart rebates[14] were approved in 2015 (vs. 1,495 in 2014). For *Commercial Upstream Cooling*, a circuit rider was used to provide field support.

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[14] Source: Peregrine interview with CLEAResult

Lockheed Martin Services has also been involved in this program, promoting advanced thermostats and energy efficient water heaters to big box home improvement retailers.

In evaluating FTEs associated with the program, Peregrine counted the employees of vendors under direct contract to National Grid, but did not include labor associated with installation of this equipment, since it did not increase incrementally as a result of the Program.

Income Eligible Residential Programs

Income Eligible (low-income) programs were offered to National Grid customers in single family (1-4 unit) dwellings and multifamily (5 or more unit) buildings or developments that were eligible for the Low Income Heating Assistance Program (LIHEAP). Because this target audience was already being provided with some energy related assistance already through federal and state programs, National Grid's strategy was to piggyback on and complement and support these existing programs.

Specific 2015 Income Eligible Residential Programs, included:

Income Eligible Single Family (gas and electric)

The Income Eligible Single Family program provided low-income customers with home energy assessments, installation of energy efficient lighting, appliances, heating systems, domestic hot water equipment, and weatherization measures.

Delivery:

The Income Eligible Single Family program was provided through local Community Action Program (CAP) agencies that were under contract to the Rhode Island Department of Human Services (DHS) to deliver federally funded Weatherization Assistance Program (WAP) and the Low Income Heating Assistance Program (LIHEAP). All seven Rhode Island CAP agencies participated in and delivered Single Family Income Eligible Services. They provided three types of building audits: audits focused on lighting and appliances only that installed lighting products, audits providing detailed recommendations and work orders for insulation contractors, heating system installers, and fans; and comprehensive audits that did both. BPI-certified auditors completed building assessments and work orders. Special AMP (appliance management program) auditors installed lights and refrigerator measures.

Independent weatherization contractors installed the insulation and completed air sealing for the CAP agencies. These contractors were selected off a state-approved list and offered fixed pricing statewide for installed measures. Each agency had three to five insulation contractors it typically worked with. The CAP auditing staff inspected completed insulation work post-installation to ensure it was properly installed. Heating system upgrades were put out to bid to heating contractors, and heating contractors also were used for post-installation inspections.

In July 2013, CLEAResult, with offices in Providence, Rhode Island, became the manager of the Income Eligible Residential program and has continued in that role in 2014 and 2015. CLEAResult has been responsible for training, quality control, and oversight of National Grid-funded services and installations delivered through CAP agencies. CLEAResult also served as the conduit for National Grid payments to the CAP agencies, and they worked closely with the Rhode Island DHS staff to coordinate delivery of National Grid-funded services and traditional Weatherization Assistance. CLEAResult staffing included a program manager, an installation quality assurance / quality control inspector, and administrative support.

ACTION, Inc., based in Massachusetts, was hired to manage the refrigerator replacement service provided to income eligible residential customers. This included product procurement, ordering, delivery, removal and disposing of old appliances, and conducting quality assurance surveys.

Income Eligible Multifamily (gas and electric)

In 2013, the Company consolidated energy efficiency offerings for income eligible multifamily properties with five or more units into the Income Eligible Multifamily program, which continued in 2014 and 2015. This suite of programs addressed both gas and electric opportunities, which were previously offered as part of EnergyWise or Large Commercial Retrofit. Comprehensive energy services available to these customers included energy assessments, incentives for heating and domestic hot water systems, cooling equipment, lighting and appliances. Services are coordinated with delivery of the EnergyWise Multifamily program, but tracked separately. Additionally, the Residential New Construction program worked with Rhode Island Housing, local housing authorities, and developers of income-eligible housing to encourage construction of energy efficient properties.

Delivery:

In conjunction with its delivery of EnergyWise Multifamily services, RISE Engineering, based in Cranston, Rhode Island, had primary responsibility for delivery and coordination of Income Eligible Multifamily services. RISE staff serve as project managers for retrofit projects, meeting with building facility managers, making presentations to condominium boards and owners, and writing work orders and scopes of work (e.g. for air sealing, attic insulation, lighting fixtures, and even replacement refrigerators from retailers for low-income residents. Independent contractors installed weatherization materials (insulation and air sealing) and heating equipment components.

National Grid also began a Multifamily Benchmarking initiative in 2015, supported by a grant from Chicago-based Elevate, to provide affordable housing developers and operators of public housing authorities with building-specific information about the relative energy performance of their properties. New Ecology, specialists in affordable multifamily housing energy analysis, provided this service out of its Providence office. Collaborators included National Grid, RISE, RI Housing, the RI Office of Energy Resources, and the Energy Efficiency and Resource Management Council. New Ecology screened 428 large and small multifamily buildings and met with owners to review and interpret findings. Poor performers were referred to RISE for targeted follow-on services.

Commercial and Industrial Programs

In 2015, National Grid's Commercial and Industrial (C&I) programs employed a range of delivery mechanisms, described below, to achieve National Grid energy efficiency goals in new building construction and building retrofits for large and small businesses. C&I budgets also supported energy efficiency in municipal facilities.

C&I programs differentiate between a limited set of "prescribed measures" offered primarily to smaller businesses and "custom" or "comprehensive" measures that are approved for larger businesses. While the Small Business program, described below, has a preferred contractor installing prescribed energy conservation measures with very attractive pricing, in the same way EnergyWise does in the residential market, in general, the delivery of C&I offerings increasingly has become more "market-driven" than residential programs.

C&I programs have been structured as a whole or in part to encourage independent product and service providers to market and deliver services to National Grid customers, driving sales using incentives available to them from National Grid for purchase and installation of qualifying products. This strategy allowed customers to work within existing contractor relationships to receive program incentives, and likewise allows contractors to work within existing customer relationships to identify opportunities for placing measures that National Grid wants to promote. It also meant that multiple venders can compete for a customer's business, while assuring the customer that they could bring the same National Grid incentives.

From both a jobs and a savings perspective, this has resulted in the numbers of energy services businesses directly participating in National Grid programs increasing significantly and has created new and additional opportunities for diverse vendors to promote emerging energy efficient technology to new and existing clients.

Small Business Direct Install (electric)

In 2015, the Small Business Direct Install program continued to provide direct installation of prescriptive and custom energy efficient lighting, non-lighting retrofit measures, and minor gas efficiency measures. Electric customers with average monthly demand of less than 200 kW were eligible to participate. The customer cost share for installations was 30% of the total cost of a retrofit. Further, with the On Bill Repayment (OBR) option, a customer could choose to be billed monthly for its share over a two-year period interest-free for the amortized OBR amount.

The Direct Install program also included the SBS Coolers sub-program, which provided refrigeration controls and other refrigeration improvements to eligible customers. These measures included fan controls, cooler and freezer door heaters, smart defrost technology, EC motors, night shut off controls for novelty coolers, and LED lighting for refrigerator applications.

Delivery:

The Direct Install program's lighting and non-refrigeration measures were delivered by RISE Engineering of Cranston, Rhode Island and sourced from one product vendor (Rexel, formerly Monro Distributing). Both RISE and Rexel were selected through a competitive bidding process.

Nearly 1,340 customers participated in this program in 2015, up from the 1,050 customers participating in 2014, an increase of nearly 30 percent[15]. RISE provided turnkey installation services to this market, with annual goals, and accounted for just fewer than 80% of the customers serviced. The remaining 20% of customers served was through the Customer Directed Option or "CDO", initiated in 2014 and described below.

RISE staff engaged in the Small Business program included employees responsible for marketing and lead generation and staffing an intake center that was responsible for pre-qualifying potential customers. RISE energy specialists performed field audits of customers' facilities, and data entry staff used completed audits to generate proposals for customers. Audits also resulted in referrals to the Commercial and Industrial Gas Program. When a customer accepted a proposal, RISE project managers ensured that sufficient product was available, issued that product to installer/electricians, and ultimately closed out the work when the installation was completed. RISE maintained a supervised warehouse for material distribution and materials handlers. Electricians were both RISE employees and employees of sub-contractor Superior Electric. RISE also employed back office and accounting staff to service this program. In general, RISE employees supporting this program were salaried or hourly, while subcontractors were paid for installation work on a piece basis. Total employment from RISE and its sub-contractor Superior Electric associated with the Small Business program totaled 43.5 FTEs[16]. RISE also used two HVAC firms as controls subcontractors for installation of custom measures.

[15] Source: National Grid program statistics

[16] Source: RISE Engineering

As noted above, customers could also choose to use their own preferred electrician through the "Customer Directed Option" of the Small Business program. In 2015, over 250 customers used this option, working with nearly 25 separate firms[17].

National Resource Management (NRM), based in Canton, Massachusetts, once again delivered the SBS Coolers sub-program in 2015, which focused on controls and equipment upgrades for commercial refrigeration. NRM staff included administration and support personnel (some with technical specialties), sales representatives, and equipment installers, totaling 6.4 FTEs. Sales staff worked out of their homes in Rhode Island.

As was the case with residential programs, National Grid used CMC Energy Services, Inc. to provide quality assurance inspections of Small Business projects. Eight field inspectors conducted QA visits in Rhode Island and Massachusetts for the Small Business program as well as for the Large Commercial Retrofit and Upstream Lighting programs (described below), supported by schedulers and data entry staff. Approximately 2.25 FTEs of this team were engaged in National Grid's commercial and industrial programs in Rhode Island.

Large Commercial Retrofit (electric)

Large Commercial Retrofit is a comprehensive retrofit program designed to promote the installation of prescriptive and custom configurations of energy efficient electric equipment such as lighting, motors, and heating, ventilation and air conditioning (HVAC) systems, controls, and even combined heat and power systems in existing buildings. All commercial, industrial, and institutional customers are eligible to participate. Participating customers tended to be larger (i.e. have a monthly demand of 200 KW or more) or were pursuing "custom" electricity saving measures not available through the prescriptive Direct Install program. As was the case for the Small Business program, National Grid paid incentives to assist with defraying part of the material and labor costs associated with installing energy efficient equipment; but incentives available through this program were generally less generous than through the Direct Install program, with customers paying a larger percentage of the installed cost of measures.

National Grid also offered technical assistance to customers to help them identify cost-effective conservation opportunities.

Delivery:

<u>Installations</u>

The Large Commercial Retrofit program in 2015 continued to be a primarily market-based

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[17] Source: National Grid program statistics

initiative with no formal program administrator or designated suppliers. National Grid established performance standards for energy measures and allowed customers to select suppliers and installation vendors. Again, as described above, National Grid paid incentives that helped defray a portion of the material and labor costs associated with installed energy efficient equipment.

National Grid statistics for the 2015 Large Commercial Retrofit program identified projects for around 510 individual customers. The 14 National Grid-approved Project Expeditors ("PEX") pursued, secured, and installed 217 of these projects, of which 132 (61%) were lighting retrofits, 15 were HVAC projects, 12 were variable speed drives, and the additional 58 were "custom" or comprehensive projects, often involving multiple energy efficient technologies, that received customized incentives from National Grid. Of the 217 total projects installed by the PEX vendors, three firms installed 173 (80%) of them: Energy Source, Inc. (94), RISE Engineering (44) and Energy Conservation, Inc. (35). Continuing a growing trend observed in 2013 and 2014, these expeditors engaged dedicated sales / project management staff and aggressively pursued potential customers, in many cases then subbing out the field work to licensed electrical contractors and technology specialists who received unit-based fees for completing installations.

There were over one hundred other Installation Contractors active in the Large Commercial Retrofit program in 2015, who also used the program as a means to induce customers to upgrade existing systems to improve energy efficiency or purchase and install qualifying energy efficient equipment. These vendors included general energy contractors and energy services companies, as well as purveyors of energy saving technologies, such as energy management systems, advanced lighting systems, process equipment, HVAC components, etc. Between them, they completed an additional 292 projects. Of these projects, 151 were for lighting (51%), 95 were "custom" projects, 34 were for variable speed drives, and 12 were HVAC projects.

<u>Technical support</u>

To further support large commercial customers, National Grid contracted with consulting engineers who could be assigned at the request of an account manager to assist a customer with identifying potential custom projects and to evaluate or model the energy savings that would result, including completing required program applications. Some of these consultants brought expertise in such specialties as data center energy efficiency improvement or laboratories and clean room technology. In other situations, the customer could propose his own engineer with a scope of work that National Grid might elect to support. Additional support was available from contracted consulting engineers to witness project commissioning, to confirm that the installed measures were operating and performing as anticipated, and to ensure that predicted savings would be achieved.

In a similar vein, National Grid contracted with CLEAResult, the parent company of Portland, Oregon-based PECI, through its Massachusetts office, to offer the Energy Smart Grocer sub-program, which helped large and small supermarket chains identify and implement energy efficiency improvements. Working in 60 kW or larger supermarkets, CLEAResult focused on refrigeration improvement and some lighting. CLEAResult employed auditors and other technical staff to identify and develop refrigeration improvement projects, help engage contractors to complete upgrades, provide technical support as needed, and perform quality assurance inspections of installations. In total, 114 customers were served in 2015, up from 73 projects in 2014 and 69 projects completed in 2013[18]. These customers were part of 17 different parent accounts, representing a significant increase in the numbers of local and regional chains participating in the program, in large part through expanded outreach through the RI Food Dealers Association. Over 25 CLEAResult staff logged 2.3 FTEs providing these support services, with installations completed by independent contractors selected by customers.

Supply channel initiatives

National Grid's Commercial and Industrial Upstream Lighting program encourages customers to choose higher efficiency lighting products at the point of purchase. The assumption was that commercial customers were going to larger lighting distributors to purchase replacement lighting as it naturally failed and for large-scale change-outs. A program requirement was that this product could not be purchased and stored, but must be installed right away to generate immediate savings. The program's concept was to bring the incremental cost of the more efficient products available at distributors in line with now-conventional products so customers opt for high efficiency and lost opportunities for efficiency improvement could be avoided.

National Grid hired ECOVA to manage, support, and promote Upstream Lighting. ECOVA engaged manufacturers and calling on distributors. They offered incentives from National Grid to reduce list prices of certain energy efficient products to electrical contractors and businesses, with the goal of transitioning and transforming stocking behavior. ECOVA processed incentives and managed a quality assurance process to ensure that recorded sales were legitimate. National Grid contracted with Competitive Resources to conduct inspections to confirm that the purchased product had been installed[19].

In 2014, 429,034 units of lighting had been sold through upstream lighting. Of these, 261,820 were high efficiency linear fluorescent lamps (LFLs) replacing standard efficiency tubes. There were also 167,214 units of LED product sold. In 2015, the total volume of product sold fell to 327,420, in part due to less promotion of the program by National Grid, a drop of 24%. At the

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[18] Source: Peregrine interview with CLEAResult

[19] Source: CMC Energy Services, DBA Competitive Resources Inc.

same time, the number of LFLs sold fell from 261,820 to 75,520, a drop of 71%, while sales of LEDs increased from 167,214 in 2014 to 251,900 in 2015, growing 50%.[20]

In 2015, National Grid required that all products purchased through Upstream Lighting at a subsidized price be installed immediately (i.e., not be stored and used to replace failed lamps in the future). Given the large volume of product sold under the program, Peregrine was curious how much labor the installation of Upstream Lighting products represented.

Given our lack of information about the identity of the many individuals doing these installations, how long each of them would take to do this work, and what the basis was for their compensation (e.g. salaried, hourly, fee-based, or unit-based), Peregrine applied the same product-specific per-unit-installed times provided to us by vendors that Peregrine used to calculate FTEs for lighting installations by electricians under the Direct Install and Large Commercial Retrofit programs. We reasoned that because those installation times reflected the high productivity of experienced electricians incentivized to work quickly, the resulting FTEs calculated would be a conservative number that did not overstate labor hours.

Using this methodology, we calculated that the total 327,420 units of product sold through Upstream Lighting in 2015 would require, at a minimum, a total of 31.8 FTEs to install. However, we recognized that not all of this labor should be counted as part of this study since many of the purchasers were National Grid electric customers whose employees were most likely installing products as part of their normal job duties.

Digging deeper into the Upstream Lighting data provided by National Grid, Peregrine found that a significant portion of the product purchasers were electrical contractors who were buying and presumably installing products at customer facilities. These 350 electrical contractors accounted for 13 FTEs of the total 31.8 FTE installation labor calculated, or 41% of the installations of product sold. Electrical contractors were, per the program design, using the discounted pricing of these products available from the lighting distributers they frequent to upsell customers to replace standard efficiency lighting with high efficiency product, further driving the market transition. Some contractors, most notably Energy Source Inc. who purchased 48,000 units of lighting or 15% of the Upstream Lighting product purchased in 2015, were particularly active participants in the program.

Large Commercial New Construction (electric)

The Large Commercial New Construction program encouraged energy efficient design and construction practices in new and renovated commercial, industrial, and institutional buildings.

[20] Source: Ecova

The program also promoted the installation of high efficiency equipment in existing facilities during building remodeling and at the time of equipment failure and replacement. The program offered incentives to eliminate or significantly reduce the incremental cost of high efficiency equipment over standard efficiency equipment and provided technical support to assist customers to identify opportunities for incremental efficiency improvement in eligible buildings.

Delivery:

The New Construction program is administered internally by National Grid. As noted above, it offers both technical and design assistance to customers to identify opportunities for incremental efficiency improvement in new building designs and to help customers and their architects/engineers to refine their designs to capture these opportunities.

Outside consultants are brought in to assist customers to identify and incorporate energy efficiency solutions into new construction designs and to complete detailed studies that model and quantify energy savings. Commissioning or quality assurance is also offered to ensure that the equipment and systems operate as intended. For example, one such technical consultant, SMMA, in collaboration with National Grid's strategy team, helped provided outreach to non-profits, schools, or municipal buildings between 20,000 and 50,000 square feet in area and critiqued proposed construction projects to optimize long-term energy performance.

For purposes of this study, as is the case with Residential New Construction, construction jobs associated with commercial new construction were not counted because National Grid's involvement primarily impacts what equipment is installed and construction labor does not measurably increase in these projects.

Commercial and Industrial Gas Programs

Commercial and Industrial Gas programs supported installation of energy efficient gas heating and water heating systems, certain thermal envelope measures, and custom gas systems in existing buildings and in new construction. The program guidelines for measure eligibility were the same as for the Large Commercial Retrofit program and the New Construction program. Retrofit measures must demonstrate that they will result in added efficiency beyond existing still functional equipment. For new construction or with failed equipment, the "lost opportunity" rules apply. New equipment, to be eligible for incremental incentives, must exceed the efficiency of what codes require. All commercial, industrial, and institutional customers were eligible to participate.

The Commercial and Industrial Gas programs also offered technical assistance to customers to help them identify cost-effective conservation opportunities and paid incentives to assist in defraying part of the material and labor costs associated with the energy efficient equipment.

Delivery:

RISE Engineering served as National Grid's Program Administrator for gas programs. RISE employees working on this project included a program manager and project coordinator, mechanical and electrical engineers, field staff performing audits and minor installations, and administrative personnel and support staff. A total of 8.3 FTEs from RISE serviced the Rhode Island program. RISE Engineering's Program Manager has described RISE's role in the program as "the gears that keep moving applications forward."

RISE received leads from a variety of sources, including project expeditors, mechanical contractors, and suppliers of equipment such as steam traps. RISE would then generate a Program application and as necessary or appropriate, review the customer proposal or undertake a scoping study. If the project proposed was acceptable (i.e. met National Grid's standards), RISE issued an offer letter to the customer authorizing the project to proceed. Customers had responsibility for arranging for and completing the installation. RISE performed a post-installation inspection and closed out the application so that the rebate could be issued.

Employment Impacts of National Grid Programs

2015 Program Budgets and Full Time Equivalent Employment

Peregrine found that an estimated 695.8 full-time equivalent jobs or "FTEs"[21] resulted from National Grid Rhode Island energy efficiency programs in 2015. The table on the following page summarizes the job impacts of the 2015 electric and gas energy efficiency programs, by program and by program sector. In the table, Program Support Service Provider FTEs have been allocated and integrated into individual program FTE counts and program sector FTE counts based on spend. These are added to the Direct Service Provider count for each program. Smaller programs with limited FTE counts, including pilots and community initiatives were combined into the category titled "other". Community Action weatherization assistance program staff and National Grid staff are counted in the 695.8 FTE total, but presented separately in the table.

Peregrine was not able to develop actual head counts of individual workers participating in delivery of and support for the 2015 National Grid programs in Rhode Island. However, Peregrine can say with confidence, based on interviews with companies directly involved in the implementation of National Grid's energy efficiency programs and though our analysis of field delivery, that the number of individual workers employed in and compensated for work on Rhode Island energy efficiency programs far exceeds the total FTEs.

As described in the Energy Efficiency Program Delivery section, many companies told Peregrine that they employed multiple individuals with specialized skills or in discrete roles that were important to delivering a comprehensive, high quality product or service; but only a portion of each employee's total annual hours were attributable to Rhode Island energy efficiency activity.

Some examples:

- National Grid calculated that there were 41.6 FTE National Grid employees who worked on Rhode Island energy efficiency programs in 2015, with over 85,000 hours billed against Rhode Island accounts. That FTE count represented the aggregated contributions of many more individual National Grid staff supporting energy efficiency in Rhode Island. These were a mix of Rhode Island-dedicated employees and employees with system-wide or similar other-state responsibilities who contribute fractionally to the Rhode Island FTE total.

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[21] Peregrine and National Grid have defined a FTE for purposes of this study as 1,760 annual hours of employment (or 220 total days of employment per FTE).

2015 Full Time Equivalents by Program

PROGRAMS	2015 SPEND	TOTAL FTES
ELECTRIC PROGRAMS		
COMMERCIAL & INDUSTRIAL (C&I) TOTAL		**210**
C&I Financing	$4,000,000	**0**
Large Commercial New Construction	$8,538,704	1
Large Commercial Retrofit	$20,809,356	146.6
Small Business Direct Install	$10,734,963	60.6
Other	$146,850	1.8
LOW-INCOME RESIDENTIAL TOTAL		**37**
Single family Income Eligible Services	$7,067,927	28.6
Income Eligible Multifamily	$2,320,262	8.4
RESIDENTIAL TOTAL		**125.4**
Energy Wise	$9,782,191	97.2
EnergyStar Appliances	$1,931,580	10.1
EnergyWise Multifamily	$3,345,002	4.3
Home Energy Reports - Residential	$2,339,660	3.4
Residential New Construction	$1,003,693	3.1
Energy Star HVAC	$1,342,303	0.2
Energy Star Lighting	$6,905,723	1.6
Other	$1,047,130	5.5
NATURAL GAS PROGRAMS		
COMMERCIAL & INDUSTRIAL (C&I) TOTAL		**32**
Large Commercial New Construction	$1,843,675	0.9
Small Business Direct Install - Gas	$203,426	0.7
Large Commercial Retrofit	$3,226,992	23.9
Commercial & Industrial Multifamily	$705,437	5.8
Other	$50,774	0.7
LOW-INCOME RESIDENTIAL TOTAL		**43.8**
Single family Income Eligible Services	$2,682,705	23.4
Income Eligible Multifamily	$1,756,655	20.4
RESIDENTIAL TOTAL		**172.1**
Energy Star HVAC	$1,524,766	0.2
Energy Wise	$4,877,620	142.9
EnergyWise Multifamily	$1,694,198	26.2
Home Energy Reports - Residential	$455,512	.6
Residential New Construction	$450,772	1.4
Other	$71,851	0.8
COMMUNITY ACTION WEATHERIZATION STAFF		**34**
NATIONAL GRID STAFF		**41.6**
GRAND TOTAL		**695.8**

- Engineering firms that provided technical support, both general and specialized, to commercial and industrial programs, that provide energy efficiency services to multiple electric and gas utility companies and/or to multiple National Grid-serviced states, and dispatch staff when requested to assist individual Rhode Island customers. The intermittency of these Rhode Island requests and the necessary economics of maximizing staff utilization create a situation where Rhode Island customers are best served by engineering firms that also serve other larger markets. The Energy Smart Grocer program delivered by CLEAResult exemplifies this situation, with 25 employees based in Portland, Oregon and Springfield, Massachusetts, including three "local" field staff that did actually visit Rhode Island, used 2.3 FTEs in 2015 to work with 114 Rhode Island customers. Over the same period, CLEAResult worked with 380 National Grid customers in Massachusetts.

At the same time, for other service providers whose business focus is supporting utility initiatives and providing utility program services, the number of FTEs and the number of staff contributing to those counts may be nearly equal. For example, Rhode Island-based RISE Engineering was the lead vendor for many of the largest programs offered in Rhode Island by National Grid, including EnergyWise Single Family and Multifamily, Small Business Direct Install, and the Commercial and Industrial Gas programs. The larger size of these programs required and enabled RISE to employ full-time staff to serve in specific program roles, such as auditors and inspectors. Also, similarities between staffing needs across multiple programs, e.g. for engineering, materials handling, or accounting, allowed RISE to pool staff to provide higher levels of utilization and improved staffing economies. Additionally, similarities in technical needs between programs, e.g. for electricians, allowed RISE to employ a baseline number of full-time technical specialists, but then supplemented them on an as needed basis with sub-contracted assistance. But, at the same time, as new business opportunities in neighboring states have emerged and been secured, RISE has been able to grown further, shifting specialized staff back and forth between states as demand for services dictates, while maintaining or increasing the efficiency of staff utilization and improving labor economics.

As the table shows, the number of FTEs attributable to different programs was not necessarily proportionate to the relative size of program spending. For example, the Large Commercial Retrofit program included a significant installer labor component because the program replaces fully functional equipment. On the other hand, point-of-purchase programs like Upstream Lighting that use incentives to change buyer choices and supplier behaviors, may also replace fully functional equipment, but we assume that customer employees, who we not count as program-driven labor, install a large portion of this replacement lighting. Likewise, both residential and commercial New Construction programs impact the choice of materials, equipment, and construction techniques, but do not significantly increase amount of labor and time needed to construct the building.

Another factor influencing the number of FTEs associated with program spend was whether the energy efficiency measures installed, on a per dollar spent basis, were more labor intensive or equipment intensive. For example, weatherization materials (e.g., cellulose insulation, caulking, foam) to improve thermal performance and reduce air leakage in residential buildings (i.e. for installed insulation and air sealing) are simple and inexpensive. Most of the cost associated with weatherization is labor during the installation process. Other energy efficiency measures such as energy management controls systems, chiller and boiler replacement, or major HVAC upgrades deploy sophisticated, factory-manufactured equipment where the equipment is perhaps the greatest portion of the measure cost. While these measures often require design engineering as well as field labor to install, the considerable manufacturing labor hours is not represented in program FTE counts, so the FTEs per dollar spent is lower.

A countermanding force in terms of job impacts continues to be the ongoing desire of regulators and program administrators to increase the energy saved for each dollar spent. National Grid uses competitive bidding where practical to secure materials and labor vendors, requiring would-be contractors to devise strategies to tighten their belts and structure their workforce ever more cost effectively. Contractors have been increasingly paid on a fixed fee or a performance basis, encouraging them to keep their labor costs down, not only to be more competitive, but also to maximize margins. A vendor delivering a program or performing an installation who is not compensated on an hourly basis naturally looks for ways to maximize worker productivity, resulting in less labor required overall to achieve energy reduction goals and fewer FTEs for Peregrine to count.

Comparing 2015, 2014, and 2013 FTEs

Peregrine has calculated that 695.8 full-time equivalent jobs or “FTEs” were attributable to National Grid’s Rhode Island energy efficiency program spending in 2015, compared to 666.1 FTE jobs in 2014, and 558.9 FTEs in 2013. This represents an increase of 25% over the three years. Over the same period, total energy efficiency program spending and resulting savings increased as well.

During 2013, 2014, and 2015, National Grid’s programs and delivery strategies were not substantively different. The growth in job impacts over those years reflects increased customer and trade ally participation in National Grid energy efficiency programs, increased demand for energy efficient products and related services, and expanded service delivery. Over the same time frame, electric savings grew from 2.1% of 2012 sales in 2013 to 2.9% of 2012 sales in 2015, while gas savings increased from 0.87% of 2012 sales to 1.2% of 2012 sales. The following section examines trends over the three years and makes several observations regarding impacts that program design, participation, and other dynamics may have on FTEs.

FTE Job Impacts by Program, 2015, 2014, and 2013[22]

	2015 FTEs	2014 FTEs	2013 FTEs
Electric Programs			
Residential Non-Income Eligible	125.4	109.0	98.8
Residential Income Eligible	37.0	38.6	24.1
Commercial and Industrial	210.0	199.5	142.6
Gas Programs			
Residential Non-Income Eligible	172.1	178.0	159.1
Residential Income Eligible	43.8	42.5	34.9
Commercial and Industrial	32.0	27.0	30.3
Community Action Agency staff	34.0	32.5	30.7
National Grid staff	41.6	38.9	38.5
TOTAL RHODE ISLAND FTE JOBS	695.8	666.1	558.9

Increased customer participation

One trend observed over the three year period is that programs experiencing increases in participation tend to experience increased FTEs. For example, the EnergyWise 1-4 Unit Building program for gas and electric customers experienced a growth in audit completions over the three years, with 7,800 audits delivered in 2013, 8,654 in 2014, and 10,055 in 2015. Over this same time period, combined electric and gas FTEs associated with the program increased from

[22] FTEs for 2014 and 2013 were updated to reflect a change in the methodology for counting multifamily and commercial insulation installation labor for 2015 and therefore do not match the previous reports. The updated methodology was applied to the previous counts in multifamily and commercial electric and gas programs so trends could be compared across the three-years. Detailed methodology can be found in Appendix A, page 39.

211.2 in 2013 to 240.1 in 2015. A similar trend is found in the EnergyWise Multifamily and the Income-Eligible Multifamily programs, delivered to both gas and electric customers by RISE Engineering. 4,312 market rate units and 4,876 income eligible units participated in the program in 2015, up from 3,400 market rate and 4,000 income eligible multifamily units in 2014. With this increase in participation, there was a combined corresponding increase from both programs delivered to both gas and electric residential customers from 46.7 FTEs in 2014 to 59.3 FTEs in 2015. Lastly, this can also be seen in the C&I sector where participation in the Large Commercial Retrofit program (electric) increased from 348 customers and 484 applications in 2013, to 430 customers and 578 applications in 2014, and to 459 customers and 614 applications in 2015, with corresponding increases in FTEs.

Broader trade ally engagement

National Grid continued to move away from program delivery models that limit participating vendors to being direct contractors to National Grid and their sub-contractors. This has expanded the opportunities for trade allies to initiate projects with new or existing customers, supported by direct access to National Grid incentives. This has been particularly true in programs serving commercial and industrial customers where one can see an increase in FTEs over the three-year period, particularly in the electric sector. Notable examples of this trend include the Large Commercial Retrofit program (electric) described above where installation contractors, suppliers, and project expeditors drove the sale and installation of energy efficient projects; the Small Business program where an increasing number of electrical contractors are participating under the Customer Directed Option, exploiting existing relationships; and Commercial Upstream Lighting, where electrical contractors used the discounted pricing of products available from lighting distributers to upsell customers to replace standard efficiency lighting with high efficiency product, further driving the market transition.

Changing Measure Mix

In 2014, there had been a significant jump in FTEs supported by the Large Commercial Retrofit program (electric) due to the Toray Plastic America's 12.5 MW combined heat and power project. This project alone had resulted in 42 FTEs of jobs in 2014.

But even without a similarly large CHP project in 2015, the Large Commercial Retrofit program (electric) continued to see an increase in FTEs. We conclude that this is most likely a reflection of the different mix of technologies installed in 2015 and the relatively higher labor intensiveness of installed costs. The units of prescriptive lighting products installed through the Large Commercial Retrofit program increased from 32,692 in 2014 to 89,701 in 2015. These were primarily conversions to LED lighting, with a resultant increase in associated labor from 34.3 FTEs to 71.2 FTEs, an increase nearly equal to the total FTEs associated with the Toray CHP project in 2014.

Additional drivers affecting total FTES

Peregrine also found that total FTEs in the residential sector, generally associated with installation of energy efficiency measures to manage heating costs, can also vary significantly year-to-year. For example, looking at the Income-eligible residential program in 2015, there was a measurable, though not large, drop in FTEs for income-eligible electric customers served from 2014 to 2015. Total FTE's in this category fell by 4% from 2014 to 2015 after a significant jump of 60% from 2013 to 2014. During this same period, the number of income-eligible gas customer FTEs increased slightly from 42.5 in 2014 to 43.8 in 2015, though 2014 represented a significant increase in weatherization and heating system installation activity (22%) compared to 34.9 FTEs in 2013.

Such differences in FTE jobs created year-to-year and fuel-to-fuel can be caused by a number of factors. One factor is, of course, the natural variability of customer preferences, retrofit opportunities at customer residences, and the mix of measures installed as a result. Customer choice and measure mix can often be impacted by changes in energy prices and weather. The very large spike in FTEs for the installation of weatherization materials and heating systems for income-eligible electric customers in 2014 was likely due to the combination of a very cold winter with extraordinarily high oil and propane prices. This may have driven customers on limited fixed incomes to request services from Community Action Agencies. These same cold temperatures likely also drove income eligible natural gas customers to seek assistance in that cold winter, but the relatively lower cost for natural gas probably mitigated that demand and the FTEs created.

Conclusions

The FTE jobs associated with the implementation of energy efficiency services will likely continue to increase during the coming years along with the pace of increased participation and spending on these programs. While such increases in participation and spend appear to correlate closely with growth of FTE jobs, there are other factors in play that can reduce or encourage job creation over time.

- Changing energy costs can affect customer behaviors, encouraging or discouraging customer choice to invest in energy efficiency measures that would result in job creation.
- Continuing evolution of and price drops for energy technology, as has been demonstrated by the emergence and growth of LED lighting, could create new cost-effective installation opportunities for energy efficient products. In the case of LEDs, the availability of low-cost LED linear lamps in the next year or so would result in an opportunity to replace all existing linear fluorescents, re-opening a huge, labor intensive lighting retrofit market that had been maxed out by the limits of fluorescent technology.

- Program design adjustments that further encourage all natural trade allies to make use of incentives available from National Grid, enabling them to sell products and services to existing and new customers can lead to increases in FTEs.

We will watch and see how these influences and factors affect job creation resulting from expenditures for energy efficiency in Rhode Island by National Grid in 2016 and beyond.

Attachment A: Methodologies used for Assessing Employment

Program Support Service Providers

National Grid

National Grid provided to Peregrine a summary of billed hours and FTE counts for employees involved with individual energy efficiency programs in Rhode Island in 2015. Responsibilities of these employees included program planning and development, program administration, regulatory affairs, marketing, evaluation, and market research. Peregrine is reporting National Grid FTEs as a separate category for purposes of this study and not allocating them to specific programs or groups of programs.

Support Services Contractors

Peregrine interviewed most of the larger contractors who supported National Grid in these activities, and they described their roles and responsibilities and provided counts and hours for employees supporting National Grid in Rhode Island. Often, the FTEs Peregrine is reporting represent the aggregation of small numbers of hours by numbers of employees. Often, this was because the contractor's role was required contributions from many members of a multi-disciplinary team. Depending on the nature of the services provided and whether the support role could be associated with specific programs, time of these contractors is assigned to programs according to the overall allocation of gas and electric spend by program sector (Residential, Residential Income Eligible, Commercial and Industrial), or allocated to a specific program sector.

Direct Service Providers

Employee numbers reported by Direct Service Providers was a primary input to FTE counts. Peregrine Interviewed the major contractors directly engaged by National Grid to support or deliver Rhode Island programs to get information about type, number, and responsibilities of personnel employed. Some of these contractors provided the same services in 2015 to National Grid customers in multiple states and in some cases to multiple utilities, often using the same team of employees. Peregrine relied on their informal calculations of allocations of time to Rhode Island when formally reported hours from time cards were not available.

Where employer-sourced information on employment was not available, Peregrine relied on program records and statistics for 2015 to calculate person-hours, person-days, and ultimately annual full time equivalent field staff. Peregrine used Totals for individual energy efficiency measures installed or, in some cases, totals of specific products installed in 2015 to calculate FTEs by multiplying the average time required (in person-hours or person-days) for each installation by the number of installations and converting the result to FTEs based on an assumed 1,760 work hours per year or 220 work days per year. These unit-based installation times were secured from representative installation companies that performed this work or from organizations that supervised installation activity. In cases where major employers could provide actual installer hours of work to Peregrine, those actual hours or days of work were used instead of calculated FTEs.

Residential Programs

EnergyWise 1 – 4 Unit Residential Program

For the EnergyWise Residential program, Peregrine spoke with RISE Engineering's program manager who provided an overview of how the program functions and changes from 2014, as well as updated FTE counts of RISE employees in various roles based on payroll tracking. We then allocated this total number of FTEs to gas and electric programs.

In 2014, RISE had shared general rules of thumb for how weatherization contractor crews and heating contractors perform site work that had been borne out by direct interviews with a sample of the insulation installation companies and interviews with community action program supervisors with similar responsibilities for low-income residential services. Peregrine continued to use these rules of thumb in 2015 to estimate numbers of FTE insulation and heating system contractor personnel that installed major energy efficiency measures.

Peregrine learned that it takes a crew made up of three insulation contractors an average of two days to complete a weatherization job (insulation and air sealing). National Grid provided counts of numbers of insulation jobs completed by each participating insulation contractors in 2015. We then used the total numbers of insulation jobs and the average number of man-days required for each installation to calculate a total number of FTEs (again, assuming work 220 days per person per year) providing insulation services in 1-4 unit buildings. FTEs were marked up by 20% to account for a contractor's support and management staff.

For heating system installations, we learned that it requires a two-person team four days on average to remove and replace a heating system. Peregrine secured counts of high efficiency heating systems and related equipment installed in 2014 from Blackhawk Engagement Solutions which processes the incentives paid out for these installations. Since Peregrine had differentiated counts for replacements furnaces and boilers, Peregrine assigned less installation time to replacement furnaces (due to less piping work) and adjusted time estimates accordingly. Replacement residential gas equipment was allocated to the gas program and replacement residential oil or propane heating equipment was treated as an expense of the electric program. Average number of hours required for an installation was multiplied by the total number of items installed. The total number of calculated hours was then divided by 1,760 hours to convert it to FTEs, and the FTEs were marked up by 20% to account for a contractor's support and management staff.

EnergyWise Multifamily Residential Program

As with the EnergyWise 1-4 Unit Residential Program, Peregrine interviewed RISE's program manager and was provided with staffing counts. In addition to general program supervision, responsibilities included technical leadership, auditing, field coordination and inspections, and electrical installation work. Again, RISE was able to convert staff counts to FTEs associated with this particular program. Peregrine relied on installation counts from National Grid to determine numbers of individual measures that had been installed by independent insulation contractors and heating contractors in these buildings. As was the case for contractors installing ECMs in 1 to 4 unit buildings, these counts were multiplied by average times for installations in hours or portions or hours, and the resulting total hour counts were divided by 1,760 hours per FTE to arrive at annual FTE counts.

<u>Adjustment to calculation methodology from prior years</u>

Calculations for FTEs for multifamily insulation work had, in prior years, always been calculated in *time per square foot of insulation installed* (unlike for the 1 – 4 unit program where calculations were based on *average total man-days per job*) that had been provided by a Program contractor in 2013. In reviewing this methodology as we began our 2015 calculations, Peregrine found it had insulation for the 1-4 unit program presented both as total jobs and as square feet of production installed and decided to compare total results using the per square foot metric and the man-day metric. In doing so we realized that the square foot metric used for multifamily and commercial insulation labor had been undercounting by around a factor of 10. We calculated and applied a new time factor for "per square feet of insulation installed" in 2015 in these buildings, based on this finding. We also revisited the calculations for multifamily and commercial insulation installation FTEs for 2013 and 2014, revised the FTE counts using the new time factor, and are using these revised total FTEs in the comparison discussion of total 2013, 2014, and 2015 job counts.

Residential New Construction
Residential Home Energy Report Program
Residential Community Based Initiatives
ENERGY STAR® HVAC Program

The residential programs in this grouping were all funded in 2015 by both residential gas and electric year-end spend. For each of these programs, there was no significant incremental labor impact associated with product installed or purchased because the program did not so much affect whether product was installed as it did which product was installed. Peregrine generated FTE counts through interviews with individual businesses that provided support services (e.g. marketing assistance, informational mailings, technical assistance and training, quality assurance inspections). These businesses provided staffing counts for 2015 from their accounting records. Total FTEs were then allocated to gas or electric based on the ratio of spending in each residential gas and electric program.

ENERGY STAR® Lighting
ENERGY STAR® Products

Both of these programs were funded solely through the residential electric budget. For both programs, there was no significant incremental labor impact associated with amount of product installed or purchased. Further, retailers' staff engaged at the point-of-sale were not counted as incremental FTEs. Peregrine generated FTE counts through interviews with individual businesses that supplied support services (e.g. marketing assistance, refrigerator recycling). These businesses provided staffing counts for 2014 from their accounting records. Total FTEs were then allocated to the residential electric spend.

Low Income Residential Programs

Income Eligible 1-4 Unit Residential

FTE counts for this program for 2014 include program management staff by the program vendor CLEAResult, Community Action Program (CAP) agency staff counts, and calculated labor required to complete installations. CLEAResult staff FTEs came from direct interviews. Total CAP agency staffing was developed from counts of staff in different roles by CAP agency that were put together by the Rhode Island Department of Human Services. National Grid provided the counts of weatherization and heating system installations completed in 2014. CAP agencies provided guidance on contractor crew sizes and installation practices that Peregrine used to calculate the numbers of FTE installers who performed this work.

Income Eligible Multifamily Residential

Peregrine used the same approach to calculating FTEs for the Income Eligible Multifamily program as for the EnergyWise Multifamily Residential Program since both programs were administered by RISE Engineering and used the same delivery strategy.

<u>Adjustment to calculation methodology from prior years</u>

As was the case with EnergyWise Multifamily installations of building insulation, Peregrine applied calculated and applied a new time factor for "per square feet of insulation installed" in 2015 in income eligible multifamily buildings, based on a determination that we had undercounted labor FTEs in prior years. As with the EnergyWise Multifamily program, we revisited the calculations for income eligible multifamily insulation installation FTEs for 2013 and 2014, revised the FTE counts using the new time factor, and use these revised total FTEs in the comparison discussion of total 2013, 2014, and 2015 job counts.

Commercial and Industrial Programs

Small Business Direct Install Program

Peregrine used counts of employees provided by RISE Engineering, the regional program administrator, to generate FTEs for RISE staff involved in program management and measure installations and for their sub-contractors as well. No actual measure counts and calculated FTEs were used to compile job counts attributable to the work of RISE and its subcontractors, as all workers were accounted for without a piecework analysis. Peregrine also calculated additional FTEs associated with the "customer-directed option" (or "CDO") that allowed customers to use an electrician they had an existing relationship with to install program measures and receive the same incentives as were available through RISE. These numbers were based on information from RISE about numbers of electrical contractors that were active through CDO and then cross tabulating this number against installation time that would be required for actual items installed.

CLEAResult provided staff counts for the Smart Grocer sub-program. National Resource Management (NRM) tallied total hours of individual support staff by responsibility, as well as provided FTE counts of installers it employed.

Large Commercial Retrofit Program (electric)

As described in the section on energy program delivery, the Large Commercial Retrofit program was the most market-based of all electric programs provided. There was no program manager under contract to facilitate or organize installation work. Customers initiated projects, as did businesses that had products or services they were trying to sell.

Peregrine used National Grid's descriptions and counts of technical assistance and installations performed during 2015 to calculate workforce impacts. They only exception to this approach was counts Peregrine secured from interviews with Project Expeditors regarding sales and project management staff they were employing to secure and oversee projects.

National Grid provided engineering services to customers through retained contractors, in particular where "custom" energy efficiency solutions required technical support to determine what could be done, what should be done, what energy savings would result, and what incentive levels were appropriate. To calculate the FTEs associated with technical assistance support provided by engineers under contract to National Grid, Peregrine took the total dollars paid out for this work and calculated how many hours of labor it represented at an assumed $120 per hour. Total hours were then converted to FTEs.

Installation work performed was treated in a number of ways, depending on how much information was available to Peregrine in the data sets supplied by National Grid. For Upstream

Lighting, National Grid provided counts of product sold, which Peregrine converted to installation hours using per unit labor requirements and then counted the times for installations by electrical contractors that purchased these materials on behalf of customers.

Large Commercial Retrofit projects that were identified as part of a specific technology group (e.g. lighting, motors) and that had counts of products installed were the easiest to develop FTE estimates for. In other cases, particularly "custom" projects where installation numbers might be missing or no separate labor cost component of projects is identified to National Grid for these projects, Peregrine extrapolated labor required from total cost. Peregrine used the average installation times provided to us by installation vendors to estimate workforce requirements and number of hours or days (for more labor intensive projects) per installation and converted this to FTEs. In doing these calculations, Peregrine did not concern itself about whether the contractor of record for the job was a customer, a general contractor, or an installation contractor. We assumed that installation contractors who were motivated to work as efficiently as possible were doing the installation work.

For larger, more complex custom projects, the energy efficiency project component of the total cost may only be a portion of the total project cost identified in the National Grid database so Peregrine used incentive levels paid out to tease out the total efficiency project cost. This required comparing incentives paid for simple projects and the complex custom projects covered by the program to determine the efficiency project size. Once the size of the efficiency project was determined, we could apply assumptions about the ratios of labor cost to material cost for different technologies and calculate the type and number of labor hours this represented, aggregate the total hours, and convert them to FTEs.

Commercial and Industrial Gas Programs

The Commercial and Industrial Gas programs were managed for National Grid by RISE Engineering, and Peregrine interviewed RISE to secure counts of RISE employees and FTEs. A variety of contractors installed energy efficiency measures installed. Peregrine used measure counts that National Grid provided to calculated how many FTEs of labor they represented, applying average installation times provided to us by installation vendors, determining how many hours or days were required in aggregate, and converting these hours or days to full-time equivalent jobs.

Attachment B: Interview Guide

National Grid 2015 RI Labor Study
Organization Interview Guide

Interview date:

National Grid Program:

Program overview and how delivered/program volumes in 2015:

Supplier company/organization:

Interviewee/position/phone/email:

Company role (i.e. services provided):

Changes from prior year?

How long has company been involved in the program? ____

Staff assigned:

- Name/Title/Role   Number / FTEs   Pay (salary, hourly, piece, commission)?

Location(s) of office(s) providing services and activities:

RI based staff?: Yes/No.   Head count? _________

Are sub-contractors used?

- Names   Roles   compensation type   Contact info

Are there installation contractors involved in service delivery to Nat Grid customers?

- Names   Roles   compensation type   Contact info

Does Program result in increased employment or additional hours for RI contractors?

Additional comments:

Attachment C: Participating Companies

The list includes contractors and subcontractors performing work directly for National Grid Energy Efficiency programs in 2015 that were counted in the FTE analysis and additional companies who assisted customers to secure equipment rebates, for example through the New Construction, High Efficiency HVAC programs, and upstream lighting. The list also includes the Community Action Program agencies and their subcontractors involved with the delivery of the low-income program, whether under National Grid funding or WAP/LIHEAP/ARRA funding.

Of the 1,009 companies, agencies, contractors and sub-contractors listed here, 793 (79%) are either headquartered in Rhode Island, or have a physical presence in Rhode Island. The list is organized first by state (alphabetically), and then alphabetically by company name. To find the Rhode Island companies, move to the first appearance of "RI" in the far right column.

Vendor	Town	State
Accurate Background, Inc.	Irvine	CA
Bigspeak Inc.	Santa Barbara	CA
Energy Efficiency Funding Group Inc.	San Francisco	CA
Interviewing Service of America	Van Nuys	CA
Nest Labs Inc.	Palo Alto	CA
Regency Lighting	Chatsworth	CA
Waypoint Building Group	San Francisco	CA
Heschong Mahone Group Inc.	Gold River	CA
Apex Analytics	Boulder	CO
E Source Companies LLC	Boulder	CO
AMCO and Co.	Dayville	CT
AMS Greensolutions LLC	Willington	CT
Best Energy Plumbing Heating Air Conditioning	Pawcatuck	CT
Competitive Resources Inc.	Yalesville	CT
D Mac and Son	Moosup	CT
DDLC Energy	New London	CT
George Chartress	Norwich	CT
Greenleaf Energy Solutions	Oxford	CT
Harrington Plumbing and Heating	Pawcatuck	CT
Irvin McLaughlin Ebd	North Grosvenor Dale	CT
JK Muir LLC	Durham	CT
Lantern Energy, LLC	Norwich	CT
Nick Zaharie	Pawcatuck	CT
Shannon NRG Resource	Waterbury	CT
Techniart Inc.	Collinsville	CT
Upland Construction Group	North Stonington	CT
Wattsaver Lighting Products Inc.	East Hartford	CT

WJR Plumbing and Heat	Voluntown	CT
American Council for an Energy-Efficient Economy	Washington	DC
Energy Solutions Center	Washington	DC
Smartpower	Washington	DC
A Led Lights LLC	Jacksonville	FL
Apollo Lighting	Fort Lauderdale	FL
Green Lumens LLC	Boca Raton	FL
Pro. Unlimited Inc.	Boca Raton	FL
Hill Phoenix Inc.	Conyers	GA
National Energy Educational Development Need	Manassas	GA
Innerworkings Inc.	Chicago	IL
Gexpro	Indianapolis	IN
3-D Lighting	Franklin	MA
A Plus J Home Air	Attleboro	MA
Action Inc.	Fall River	MA
Advanced Plumbing and Heating	Seekonk	MA
Alternative Creative Energy and HVAC Inc.	Blackstone	MA
Alternative Weatherization, Inc.	Fall River	MA
American Plant Maintenance	Woburn	MA
Anctil Plumbing and Heating Inc.	Somerset	MA
Andelman and Lelek Engineering Inc.	Norwood	MA
Anthony F Vieira III Heating and Air Conditioning	Attleboro	MA
Apollo Brothers LLC	Fitchburg	MA
Araujo Bros Plumbing and Heating	New Bedford	MA
B2Q Associates Inc.	Andover	MA
Backlund Electric Corporation	Norfolk	MA
BDL Heating and Cooling Inc.	North Attleboro	MA
Beaupre Electric	Assonet	MA
Ben Therrien Home Improvement	Attleboro	MA
Bob Costa	Seekonk	MA
Briggs Mechanical Inc.	North Attleboro	MA
Bruin Corp.	North Attleboro	MA
Building Science & Construction	Braintree	MA
C & S Electric	Groveland	MA
Caliber Building and Remodeling	Sandwich	MA
Camaras Heating and Air Conditioning Services	Westport	MA
Center for Ecological Technology	Florence	MA
Champion Resources	Ipswich	MA
Cloud Sherpas LLC	Boston	MA
Columbus Energies Inc.	Swansea	MA
Compressed Air Technologies Inc.	Shutesbury	MA
Conservation Services Group Inc.	Westborough	MA

Consolidated Marketing Services	Burlington	MA
Consortium For Energy Efficiency	Boston	MA
Controlled Temperature Heating & AC	Westport	MA
Conventures Inc.	Boston	MA
Coolidge Coolant Company Inc.	Waltham	MA
Copland Mechanical Services Inc.	South Attleboro	MA
Copperline Plumbing and Heating	Rehoboth	MA
Dalpes P and M Services Ltd	Bellingham	MA
Datasense Solutions Inc.	Waltham	MA
Deschenes Plumbing and Heating	North Attleboro	MA
DMI	Wellesley	MA
Don Dalpe Plumbing	Blackstone	MA
Douglas Ahaesy Electric	Fall River	MA
DW Smith Plumbing and Heating HVAC	Uxbridge	MA
E & V Oil Co Inc.	Swansea	MA
Ecast Video LLC	Boston	MA
Ecova Inc.	Boston	MA
Einhorn Yaffee Prescott Architecture	Boston	MA
EM Corbeil Inc.	Millville	MA
ENE Systems Inc.	Canton	MA
Energy & Resource Solutions Inc.	North Andover	MA
Energy Federation Inc.	Westborough	MA
Engineered Solutions Inc.	Natick	MA
Ferreira Builders	Attleboro	MA
FL Machado Plumbing and Heating LLC	Seekonk	MA
Forest Hills Electrical Supply Inc.	Randolph	MA
GH Electrical Service	Attleboro	MA
GM Refrigeration	Fall River	MA
Graybar	Boston	MA
Greenleaf Associates Inc.	Weston	MA
Gustave Mattos Electric Co Inc.	Fall River	MA
Heating and Air Conditioning Contractors	Swansea	MA
HVAC 360	Rehoboth	MA
IBM Corp.	Cambridge	MA
Indresano Energy Company	Wellesley Hills	MA
Inline Plumbing and Heating	Fall River	MA
Insulate 2 Save	Fall River	MA
Jaco Environmental	Franklin	MA
Jaquez General Contractor	Lynn	MA
Jarosz Plumbing and Heating	Rehoboth	MA
Jay Sheldons Heating	Seekonk	MA
JPS Plumbing Heating and Air Conditioning	Westport	MA

KEMA	Burlington	MA
Larrys Heating and Ac	Rehoboth	MA
Lavoie	Seekonk	MA
Lewis Rheaume Plumbing and Heating	Seekonk	MA
Litemor	Norwood	MA
Lockheed Martin	Burlington	MA
LS Heating and Air Conditioning	Seekonk	MA
M & M Plumbing and Heating Inc.	Rehoboth	MA
M Sardinha and Sons Plumbing and Heating Inc.	Fall River	MA
Marcs Sheet Metal Inc.	Assonet	MA
Mark Cordery HVAC	Berkley	MA
Matt Machado Plumbing and Heating	Dighton	MA
MJ Electric and Refrigeration LLC	Rehoboth	MA
Motus LLC	Boston	MA
National Resource Management	Canton	MA
NESCO	Canton	MA
New Ecology Inc.	Boston	MA
New England Energy Management Inc.	Leominster	MA
New England Weatherization, LLC	Attleboro	MA
Nexant Inc.	Burlington	MA
Next Step Living	Boston	MA
Northeast Efficiency Supply (NES)	Sutton	MA
Northeast Electrical and Mechanical Services Inc.	Walpole	MA
Northeast Energy Efficiency Partnerships	Lexington	MA
O'Brien & Neville Inc.	Holliston	MA
Olean Mechanical	Seekonk	MA
O'Neill Mechanical Services	Seekonk	MA
Opinion Dynamics Corporation	Waltham	MA
Opterra Energy Services	Norwell	MA
P & P Plumbing	West Roxbury	MA
Pacheco-Cooke Electrical	North Attleboro	MA
Patriot Sheet Metal HVAC	Seekonk	MA
Paul Whitman Electrical	Pembroke	MA
Peregrine Energy Group	Boston	MA
Propane Plus Heating and Cooling	Rehoboth	MA
Quality Climate Control Inc.	Fall River	MA
Rebello Weatherization Inc.	Swansea	MA
Reis Electric	Westport	MA
Rethinking Power Management	Boston	MA
Retrocool Energy Inc.	Natick	MA
Retrofit Insulation	Fall River	MA
Rhode Island Sheet Metal LLC	Rehoboth	MA

Rickard and Sons Plumbing and Heating	Seekonk	MA
Ritchie's Insulation	Westport	MA
River Energy Consultants	Fall River	MA
Robert Main	Seekonk	MA
Roia Jason Electrical	North Dartmouth	MA
Ronald Houde	Somerset	MA
Sacks Exhibits	Wilmington	MA
Savio Lighting	Needham	MA
Southeastern Gas Services LLC	Swansea	MA
Standard Electric	Wilmington	MA
Steam Trap Systems	Amesbury	MA
Sylvia Contracting	Acushnet	MA
Tetra Tech Ma Inc.	Boston	MA
The Cadmus Group Inc.	Waltham	MA
The Gas Man	Brockton	MA
The Heating Man	Rehoboth	MA
The Royal Flush Plumbing Inc.	Seekonk	MA
Theroux Mechanical	South Attleboro	MA
TJ's Plumbing and Heating Inc.	Attleboro	MA
TNZ Energy Consulting Inc.	Stoughton	MA
Triangle Refrigeration	Fall River	MA
Valley Plumbing and Heating	Kingston	MA
Vaughan Plumbing	Dedham	MA
Veolia ES Technical Solutions LLC	Boston	MA
Watermark Electric Co	Somerset	MA
Wayne Griffin Electric Co	Holliston	MA
Weston & Sampson Cmr, Inc.	Peabody	MA
Bulbs.Com	Worcester	MA
Earth Networks Inc.	Germantown	MD
Boyko Engineering Inc.	Gorham	ME
Douglas C Baston	Alna	ME
Controltec LLC	Allen Park	MI
Energy Management Collaborative LLC	Plymouth	MN
Compressor Energy Service	Merrimack	NH
FW Webb	Amherst	NH
IMMI (International Marketing Management, Inc.)	Portsmouth	NH
KT&T Distributors Inc.	Nashua	NH
Weller & Michal Architect	Harrisville	NH
Clear Energy LLC	Bloomfield	NJ
CMC Energy Services Inc.	Cranbury	NJ
Ideas Agency Inc.	Blairstown	NJ
Russell Marketing Research	East Rutherford	NJ

SHI International Corp.	Somerset	NJ
AM Home Delivery	Brooklyn	NY
Edoe Inc.	New York	NY
Illuminating Engineering Society	New York	NY
Integral Group	New York	NY
Integrated Marketing Services Inc.	Liverpool	NY
MRY US LLC	New York	NY
Owens Kopilak Klein Lurie	New York	NY
Ram Marketing	Saint James	NY
SPPRO Inc.	Bronx	NY
Questline Inc.	Columbus	OH
Ecobee Inc.	Toronto	ON
Real Winwin Inc.	Philadelphia	PA
2 Sons Electric LLC	East Providence	RI
2Story Design Build	Providence	RI
3Js Plumbing	Warwick	RI
A & C Burner Service HVAC	East Providence	RI
A & I Electric	Pawtucket	RI
A & J Electric	Cranston	RI
A & L Plumbing Mechanical and Consulting	Westerly	RI
A & M Compressed Air Products Inc.	Providence	RI
A & T Construction	Warren	RI
A E Costa Electrical Contractor LLC	Warwick	RI
A Perry Plumbing and Heating	Coventry	RI
A Rooter Man Plumbing Heating Drains	Providence	RI
A.R. Heating and Cooling Inc.	Providence	RI
A.T. Electric Contractors	Providence	RI
A1 Electrical Construction LLC	North Providence	RI
ABC Heating Services	Bristol	RI
Abernathy Lighting Design Inc.	North Providence	RI
ABM Enterprises Inc.	Exeter	RI
Aces Plumbing and Mechanical	North Providence	RI
Acme Electric Inc.	North Providence	RI
Acorn Maintenance	Warwick	RI
ACR Construction and Management Corporation	Pawtucket	RI
ADI Energy	Warwick	RI
ADM Contractors	Albion	RI
Advance Electrical Corporation	Providence	RI
Advanced Comfort Systems Inc.	North Smithfield	RI
Affordable Building and Weatherization Inc.	East Greenwich	RI
Affordable Heating and Air Conditioning Services	Providence	RI
Affordable Insulation Inc.	Providence	RI

AIA and Sons Construction	Warwick	RI
Air Conditioning Services Of New England Inc.	Cranston	RI
Air Metalworks Ltd	North Providence	RI
Air Synergy Cooling and Heating Systems Specialist	Providence	RI
Air Tech Heating and Air Conditioning	Rumford	RI
Air Temp	Riverside	RI
Aire Serv Heating and Air Conditioning	Pawtucket	RI
Airhart Electric Inc.	Coventry	RI
AJC Electrical Services LLC	Cranston	RI
AJ's Contractors	Providence	RI
Al Swajian and Son Plumbing and Heating	Cranston	RI
Alan Jerauld	North Providence	RI
Alan Paul Electric	Warwick	RI
Albert S Gizzarelli Plumbing and Heating Inc.	Greenville	RI
All In One Plumbing Heating and Cooling	West Warwick	RI
All Phase Heating Concepts	Woonsocket	RI
All Seasons Heating and Air Inc.	Johnston	RI
All Star Insulation	Providence	RI
Allan Menard Plumbing LLC	Pawtucket	RI
Allen Plumbing and Heating	North Providence	RI
Alliance Plumbing and Heating Inc.	Cumberland	RI
Almeida Plumbing and Heating and Air Inc.	Greenville	RI
Alpha Electrical Contractors Inc.	Riverside	RI
Alpha Mechanical	East Providence	RI
Al's Plumbing and Heating	West Warwick	RI
Alternative Heating and Cooling	Cranston	RI
AMC Construction Service	West Warwick	RI
American Development Institute Inc.	Warwick	RI
American Electric Service Inc.	Cranston	RI
American Home Heating and Air Conditioning Inc.	Providence	RI
Amity Electric	Wyoming	RI
AMJ Contracting	Cranston	RI
Anchor Insulation	Pawtucket	RI
Anchor Plumbing and Heating Company Inc.	Providence	RI
Andy's Overhead Electric	Kingston	RI
Angell Heating and Cooling	Peace Dale	RI
Anibal Ramos	Providence	RI
Anne The Plumber	Woonsocket	RI
Anthony Berard	Cumberland	RI
Anthony Januario Heating Co	Bristol	RI
Anthonys Quick Plumbing and Heating	Johnston	RI
Antonio's Electric Company	East Providence	RI

Anytime Plumbing Service	Harrisville	RI
APuzzo Plumbing and Heating	North Scituate	RI
Arden Engineering Constructors LLC	Pawtucket	RI
Ardente Supply Co Inc.	Providence	RI
Armor Plumbing	Exeter	RI
Arthor Dipetrillo Plumbing and Heating	Johnston	RI
Arthur W Adler	Bristol	RI
Aten Energy	Pawtucket	RI
Atlantic Control Systems	Exeter	RI
Atlantic Supply Inc.	Coventry	RI
Atlantis Comfort Systems Corp	Smithfield	RI
Atlas Insulation	North Scituate	RI
Auburn Electric Company	Cranston	RI
Autiello Plumbing and Heating LLC	Cranston	RI
Automatic Heating Equipment Inc.	Providence	RI
Azverde Electric Co	Cumberland	RI
B & B Consumers Natural Gas Service	Woonsocket	RI
B & J Matzner	Warwick	RI
B & K Electric, LLC	Cranston	RI
B & P Plumbing and Heating	Westerly	RI
Baptista Electric	Cumberland	RI
Barlow Heating LLC	Warwick	RI
Barradas Construction Co., Inc.	Pawtucket	RI
Barrington Plumbing and Heating	Barrington	RI
Bay Plumbing Service Inc.	North Kingstown	RI
Baynes Electric	Westerly	RI
Bayside Electric Company	Warwick	RI
Beacon Electric	East Providence	RI
Beauchemin Design	North Smithfield	RI
Berard Heating and Mechanical	Warwick	RI
Bermudez Plumbing and Heating	Pawtucket	RI
Bert Gardiner Plumbing	Charlestown	RI
Bertrand Plumbing Inc.	Pascoag	RI
Big Dog Plumbing and Heating	Ashaway	RI
Bileau HVAC Inc.	Woonsocket	RI
Bill Gardiner Plumbing and Heating LLC	East Providence	RI
Bill Gornostai Electric	Warwick	RI
Bill Handyman/Painting	Smithfield	RI
Bill The Plumber	North Smithfield	RI
Bills Heating Service Inc.	Warwick	RI
Blackstone Valley Community Action	Pawtucket	RI
Bluestone Energy Services Ltd	Providence	RI

Bob Larisas Plumbing and Heating Inc.	Barrington	RI
Bob Martel Plumbing and Heating	Central Falls	RI
Bob Sequeira	West Warwick	RI
Bodell Plumbing and Heating	South Kingstown	RI
Botelho Electric	Cranston	RI
Boucher HVAC	Wakefield	RI
Boulevard Plumbing and Heating	Middletown	RI
Bradley Plumbing and Heating	East Providence	RI
Bradley R Highling LLC	North Kingstown	RI
Brandon Schiano	Cranston	RI
BRH Electric	East Providence	RI
Brian Amadon	Coventry	RI
Brian Cargill HVAC Inc.	Cumberland	RI
Brians Heating Concepts Inc.	Tiverton	RI
Bristol County Plumbing and Heating LLC	Bristol	RI
Briteswitch LLC	Warwick	RI
Brookside Electric	Westerly	RI
Bruno & Son Electric Inc.	Providence	RI
BSH Heating and Appliance	Barrington	RI
Buckley Heating and Cooling	Wakefield	RI
Build Pros	Pawtucket	RI
Buono Electric	Johnston	RI
Burbanks Plumbing and Heating Inc.	North Kingstown	RI
Burns Cold Heating and Cooling	West Warwick	RI
Butler and Sons Plumbing and Heating Inc.	Providence	RI
BZ Electric	West Warwick	RI
C & D Mechanical	Cranston	RI
C & K Electric Company Inc.	Providence	RI
C & L Energy Corp	Cranston	RI
C.J. Nemes Inc.	Woonsocket	RI
C.W. Cummings Plumbing Company Inc.	Coventry	RI
Cal Supply Co., Inc.	Cranston	RI
Calcourt Heating Inc.	Little Compton	RI
Caldwell & Johnson Inc.	North Kingstown	RI
Calyx Retrofit	Lincoln	RI
Canales Construction	Lincoln	RI
Candela Systems	Cranston	RI
Capitol Plumbing Company	Cumberland	RI
Capwell Heating and Air Conditioning	Greene	RI
Carello Plumbing	East Providence	RI
Carjon Air Conditioning and Heating Inc.	Smithfield	RI
Carl Mancuso Construction & Plumbing Inc.	Warwick	RI

Carl Pecchia Heating Contractor LLC	Johnston	RI
Carlos Silva	Pawtucket	RI
Carter Bros Inc.	Pascoag	RI
Carter Plumbing and Heating Co.	Warren	RI
Cassana HVAC LLC	North Providence	RI
Century Heating	Smithfield	RI
Charette Plumbing	Richmond	RI
Charland Oil Company	Pawtucket	RI
Charles Doherty	Warwick	RI
Chaves Plumbing & Heating	Middletown	RI
Chris Electric Ltd	Middletown	RI
Cipriano Plumbing and Heating	Wakefield	RI
CK Contractors Inc.	Providence	RI
Clearesult	Providence	RI
Clermont Mechanical Plumbing & Heating Services	Glendale	RI
Climate Masters	Providence	RI
Coast Modern Construction	Providence	RI
Cola Plumbing and Heating Inc.	North Kingstown	RI
Colaluca Plumbing and Heating	Johnston	RI
Comfort Zone Inc.	Hopkinton	RI
Community Action Partnership of Providence	Providence	RI
Comprehensive Community Action	Cranston	RI
Conti Sheet Metal	Providence	RI
Continental Heating and Cooling Indoor Air Quality	Johnston	RI
Corrigan Plumbing	Warwick	RI
Cost Modern Construction	Providence	RI
Cox Electric LLC	Narragansett	RI
CP Plumbing	North Kingstown	RI
CRM Modular Homes	Johnston	RI
Cross Insulation	Cumberland	RI
Crown Petroleum Plumbing and Heating Inc.	Barrington	RI
Crown Supply Company Inc.	Providence	RI
Crystal Plumbing and Heating Inc.	Providence	RI
CSV Mechanical Inc.	Wakefield	RI
Cumberland MG Land LLC	Cumberland	RI
D & D Electric Company	East Greenwich	RI
D & D Home Industrial Services	North Providence	RI
D & J Plumbing and Heating Inc.	Cumberland	RI
D & S Construction Company	Lincoln	RI
D & V Mechanical Inc.	Westerly	RI
D. Costa Electric Company LLC	East Providence	RI
D. Gallagher Plumbing	Coventry	RI

Dan Bracewell	Lincoln	RI
Danfoss LLC	Johnston	RI
Daniel Charette Plumbing	Hope Valley	RI
Daniel Prentiss	Providence	RI
Daniel Simoes Electric	Exeter	RI
Daniels Plumbing	Warwick	RI
Dante Gonzales	Providence	RI
Danti and Sons Plumbing and Heating Inc.	Pascoag	RI
David Ciancio SR	Providence	RI
David E Berardinelli Plumbing and Heating	Providence	RI
David Narcisi Plumbing and Heating	Warwick	RI
David Parrillo Plumbing and Heating LLC	Hope	RI
David W Bradley Plumbing and Heating Inc.	East Providence	RI
Davidsons Plumbing and Heating	Warwick	RI
Dayco Electric	Warwick	RI
Deal Electric	East Greenwich	RI
Delmonico Enterprises -Plumbing and Heating Doc	Cranston	RI
Dels Plumbing and Heating	North Scituate	RI
Desimone Electric	Cranston	RI
Desmarais Plumbing and Heating Inc.	Johnston	RI
Dessaint Electric Co Inc.	Warwick	RI
DFS Plumbing Services	West Greenwich	RI
Difazio Electric	West Warwick	RI
Dimeglio Builders LLC	Cranston	RI
Dionne and Sons	Coventry	RI
Direct Home Improvement	West Greenwich	RI
Dirocco Plumbing and Services LLC	North Providence	RI
Divona Plumbing and Heating Co	Cranston	RI
DJs Plumbing Services	West Greenwich	RI
DK Plumbing	Pawtucket	RI
DLD Plumbing & Mechanical Co. Inc.	Tiverton	RI
Don Allard	Woonsocket	RI
Don Jordan Construction	Foster	RI
Don Mendes Electrician	Providence	RI
Donovan and Sons Inc.	Middletown	RI
DPS Plumbing and Heating	Hope	RI
Drivers Plumbing and Mechanical Inc.	Providence	RI
DSA Mechanical	Barrington	RI
Dupuis Energy	Pawtucket	RI
Durante Electric	Lincoln	RI
Dynamic Air Systems Inc.	East Providence	RI
E & M Plumbing and Heating	Foster	RI

E.G. Electric Co.	East Greenwich	RI
EA Marcoux and Son Inc.	Woonsocket	RI
East Coast Remodeling	Johnston	RI
East Greenwich Oil Co Inc.	East Greenwich	RI
Eastbay Community Action	Riverside	RI
Eastern Electric	Cranston	RI
Eastern Plumbing Co Inc.	North Kingstown	RI
Ecologic Spray Foam Insulation Inc.	Jamestown	RI
Econ Electric Contractors	Bristol	RI
Edmond Alvares	Greenville	RI
Ed's Plumbing and Heating	Tiverton	RI
Edward A Tomolillo	North Providence	RI
Edward C Silvia Plumbing and Heating Contractor	Middletown	RI
Electrical League of RI	Warwick	RI
Electrical Wholesaler Inc.	Cranston	RI
Electro-Tec Systems Inc.	Lincoln	RI
Elmhurst Engineering Inc.	Providence	RI
Emergency Response Plumbing Heating & AC	Warwick	RI
Energiwise Inc.	East Providence	RI
Energy 4 Life Building Performance LLC	Smithfield	RI
Energy Conservation Inc.	South Kingstown	RI
Energy Efficient Exteriors, Inc.	Lincoln	RI
Energy Efficient Plumbing Technologies	Cranston	RI
Energy Geeks	North Smithfield	RI
Energy One Southern Mechanical	West Warwick	RI
Energy Source LLC	Providence	RI
ESCO Energy Services Company	Newport	RI
Eurotech Climate Systems LLC	Pawtucket	RI
Evergreen Plumbing and Heating Co., Inc.	Warwick	RI
EW Flagg Plumbing and Heating	Warwick	RI
F & S Electric Inc.	Bristol	RI
Feather HVAC	Cumberland	RI
Feula Plumbing and Heating LLC	Johnston	RI
FG Lees and Son Plumbing and Heating	Providence	RI
Figliozzi Plumbing and Heating	Peace Dale	RI
First Choice Plumbing	East Providence	RI
Five Star Plumbing and Heating	Johnston	RI
Fleet Plumbing and Heating Inc.	North Scituate	RI
Fletcher Heating Burner Repairs	Ashaway	RI
FLOU PHCC First Quality Installations	Saunderstown	RI
Francis Heating and Hydronics	East Providence	RI
Francis Plumbing	Bristol	RI

Frank Dimaio Heating LLC	Cranston	RI
Frank Lombardo and Sons Inc.	Providence	RI
Fred Manuppelli Plumbing and Heating	Johnston	RI
Fredrick Bailey P&H	Johnston	RI
Fressilli Plumbing Inc.	Riverside	RI
Frontier Mechanical LLC	Providence	RI
Fullport Plumbing and Heating	Rumford	RI
G & L Electric Inc.	Woonsocket	RI
Gambit Electric Inc.	Johnston	RI
Garbiner Construction Inc.	Narragansett	RI
Gas Doctor	Providence	RI
Gas Master Inc.	Little Compton	RI
Gas Pro Inc.	Cumberland	RI
Gasman NC	Warwick	RI
Gasperts	Smithfield	RI
Gem Air Services Inc.	Pawtucket	RI
Gem Plumbing and Heating Services Inc.	Lincoln	RI
Glenn J Martinelli	West Greenwich	RI
Globex Industries Inc.	Narragansett	RI
GM Perron and Son Plumbing and Heating	North Smithfield	RI
Golden Installations	Smithfield	RI
Gordon Goncalves	Riverside	RI
Goulart Petroleum Inc.	Little Compton	RI
Granite City Electric Supply Inc.	Pawtucket	RI
Gravel Electric Inc.	Harrisville	RI
Greanseal Insulation	North Kingstown	RI
Greenville Insulation Company Inc.	Smithfield	RI
Greenwich Insulation	West Greenwich	RI
Greenwood Plumbing and Heating	Warwick	RI
Gregg Balnchette	North Smithfield	RI
Griff Electric LLC	Portsmouth	RI
Groom Energy Solutions	Providence	RI
Guardian Energy Management Solutions	Middletown	RI
Gunn Inc.	Westerly	RI
Guy Clermont Plumbing and Heating	Cranston	RI
H.K. Heating Inc.	Greene	RI
H.V. Holland Inc.	Jamestown	RI
Harris Plumbing and Heating Inc.	Narragansett	RI
Hawkes Plumbing and Heating Co Inc.	Chepachet	RI
HD Supply Facilities Maintenance	Warwick	RI
Heat Tech LLC	Warwick	RI
Heavenly Homes Plumbing and Heating	Cranston	RI

Heffernan Mechanical Services	Warwick	RI
Henderson Electric	Warwick	RI
Henry Oil	Providence	RI
HF Robinson and Sons Plumbing and Heating	Cranston	RI
HH Heating	Lincoln	RI
Hill Electrical Services	Cumberland	RI
Hodson Heating and Cooling	Harrisville	RI
Holiday Home Builders	Lincoln	RI
Holland Electric	Peace Dale	RI
Home Style Construction	North Providence	RI
Homestead Plumbing	Johnston	RI
Horizon Solutions LLC	Smithfield	RI
Houle Plumbing and Heating	Greene	RI
Howard Saucier	Pawtucket	RI
Howard's Heating Service	North Kingstown	RI
Hutchins Electric	Greenwich	RI
HVAC Inc.	Cumberland	RI
Hynson Electrical Services Inc.	Bristol	RI
Ianniello Plumbing & Heating Co	Cranston	RI
Iasimone Plumbing-Heating & Drain Cleaning Inc.	North Providence	RI
ICSNE Inc.	Warwick	RI
Industrial Burner Service Inc.	Providence	RI
Interstate Electrical Services	Warwick	RI
IPS	Cranston	RI
Ironman Heating and Cooling	Riverside	RI
Island Carpentry Inc.	Newport	RI
IWIRE Electrical Services and Fire Alarm	Providence	RI
Izzo & Sons Electric	Providence	RI
J & A Electric	Providence	RI
J & J Electric	Warwick	RI
J & J Plumbing and Heating Inc.	Johnston	RI
J & M Plumbing LLC	Coventry	RI
J & R Contractors Inc.	Coventry	RI
J Argenti & Sons Electric LLC	Johnston	RI
J Dasilva Plumbing and Drain Cleaning	Pawtucket	RI
J Dunford Plumbing and Heating	West Greenwich	RI
J Joyce Plumbing and Heating Inc.	Warwick	RI
Jack Kenny	West Greenwich	RI
Jacobson Energy Research LLC	Providence	RI
James P Insana	Portsmouth	RI
Janton Electric Contractors	West Warwick	RI
JAS Plumbing	North Providence	RI

Jatwire Electric LLC	Tiverton	RI
JD Mechanical Inc.	Greenville	RI
JD Mello Plumbing and Heating Inc.	Newport	RI
Jed Electric Inc.	Greene	RI
Jeff Berard Heating	Warwick	RI
Jefferson Electrical Corp	Pawtucket	RI
Jenkins Heating	Smithfield	RI
Jimenez Plumbing and Heating	Providence	RI
JJ McNamara Electric	Providence	RI
JKL Engineering Company Inc.	Providence	RI
JM Construction	Warwick	RI
JMAC Plumbing and Heating Inc.	Warwick	RI
Joe Chaves Heating and Plumbing	Middletown	RI
Joe Falcone Plumbing & Heating	Westerly	RI
Joe Gruttadauria Plumbing and Heating	Johnston	RI
Joe Palombo Plumbing Heating and Cooling	West Kingston	RI
Joe Roy's Plumbing and Heating	Millville	RI
Joe Soave	Providence	RI
Joe Vigneault Electrician	Riverside	RI
Joel Matzner Residential Plumbing and Heating	Warwick	RI
John Babcock Plumbing Heating Unlimited	Westerly	RI
John Berard Plumbing	North Providence	RI
John Farren	Johnston	RI
John McDonough Electrician	Exeter	RI
John Nicholson Mechanical Contractor	North Scituate	RI
John Perrault	Woonsocket	RI
John R Bileau HVAC	Woonsocket	RI
John Simard Electric Contractor	North Smithfield	RI
Johnny Home Solutions LLC	Central Falls	RI
Johnny Mack Electric	Narragansett	RI
Johnny's Oil and Heating Inc.	Providence	RI
John's Heating	Riverside	RI
Johnson and Johnson Plumbing and Heating Inc.	Saunderstown	RI
Joseph A Gelinas Plumbing	Warwick	RI
Joseph A Palmieri Plumbing	Cranston	RI
Joseph Brito	Providence	RI
Joseph Giorno Plumbing and Heating	Cranston	RI
Joseph Truppi Electric	Cranston	RI
Joshua B Tait Electric	Riverside	RI
Jouberts Heating and Air Conditioning	Warwick	RI
Jow Vigneault Electrician	Providence	RI
JP Ari Pereira	Middletown	RI

JP Island General Services	Middletown	RI
Juan Villanueva	Cumberland	RI
Julio De La Rosa	Providence	RI
Just Heat	Portsmouth	RI
K & B HVAC LLC	North Providence	RI
Kafin Oil Company Inc.	Woonsocket	RI
Kenneth Hallberg	Warwick	RI
Kenneth P Adams	Cranston	RI
Kens Heating	Providence	RI
Kesslers Sheet Metal Co Inc.	Cranston	RI
Kevin Barry	Warwick	RI
Kevin Cilley	Westerly	RI
Kevin L Masse	Johnston	RI
Kevin Lahane	Tiverton	RI
KMB Plumbing Inc.	Warwick	RI
Koolco Inc.	Wakefield	RI
Kwik Plumbing and Heating Inc.	Johnston	RI
L & B Remodeling	North Providence	RI
L & F Plumbing LLC	Cranston	RI
Laframboise Carpentry	East Providence	RI
Lain Electric Co	Providence	RI
Lambert DBM LLC	Middletown	RI
Lanagan Plumbing and Heating	Woonsocket	RI
Lance Plumbing and Heating	Scituate	RI
Landry and Martin Oil Co Inc.	Pawtucket	RI
Lang Plumbing and Heating	North Scituate	RI
Larry Giorgi Plumbing and Heating Inc.	North Providence	RI
Lauders Energy Solutions Inc.	Tiverton	RI
Lawrence Air Systems Inc.	Barrington	RI
Ledoux Electric	North Kingstown	RI
Lefevre Electric Inc.	Cranston	RI
Leidos Engineering	Newport	RI
Leonard Hines	Providence	RI
Leveille Electric	Smithfield	RI
Liberty Plumbing and Heating	Jamestown	RI
Lighthouse Contracting Services	Johnston	RI
Lighthouse Propane Inc.	East Greenwich	RI
Lincoln Energy Mechanical Services Inc.	West Warwick	RI
Louie Electric & Son	Providence	RI
Louis Avarista Jr Plumbing	Cranston	RI
Lubera Plumbing LLC	Coventry	RI
Luso Plumbing and Heating Inc.	Cumberland	RI

M & G Correias Plumbing and Heating Supplies	East Providence	RI
M & M Electric	Richmond	RI
M & R Electric, LLC	Westerly	RI
M D'Andrea Electric LLC	Portsmouth	RI
M Deltufo Plumbing and Heating Inc.	East Greenwich	RI
M.J. Bouchard Heating and Air Conditioning	Greenville	RI
Madden Electric	Little Compton	RI
Mador Electric	Providence	RI
Magnetic Electric Inc.	Warwick	RI
Mags Heating and Air Conditioning	Warwick	RI
Malone Plumbing and Heating Inc.	Cranston	RI
Maloney Oil	Pawtucket	RI
Manfredo Electric	Warwick	RI
Manning Plumbing	Warwick	RI
Marcel Multi Services	Pawtucket	RI
Marco Desrochers Electric	North Providence	RI
Marinelli & Sons Electric	West Kingston	RI
Marisa Desautel	Providence	RI
Martel Plumbing and Heating	Lincoln	RI
Massed Electric Company	Warren	RI
Mastro Electric Supply Co Inc.	Providence	RI
Mastrocinque and Sons Plumbing and Heating LLC	Portsmouth	RI
Matthew Fournier	Lincoln	RI
Matts Mechanical	Greenville	RI
McBurney Electric, Inc.	Pawtucket	RI
McCormick Electrical	North Kingstown	RI
McDonough Electric LLC	West Warwick	RI
McKee Brothers Oil Corporation	Cumberland	RI
MD Heating and Air Conditioning	North Providence	RI
Menard Electric	Manville	RI
Metro Electric	Woonsocket	RI
MH Electric	Cranston	RI
Michael Bowry	Cranston	RI
Michael Freitas Plumbing and Mechanical	Pascoag	RI
Michael J. Brown	Portsmouth	RI
Michael Newbury	Tiverton	RI
Michael Tramontano Plumbing and Heating	Cranston	RI
Mike Simone Plumbing and Heating LLC	Cranston	RI
Miller Electric Corporation	West Warwick	RI
Miller Mechanical Inc.	Rumford	RI
MJF Plumbing and Heating	Bristol	RI
MJS Electrical	Lincoln	RI

MO Refrigeration	Warwick	RI
Modern Mechanical LLC	Woonsocket	RI
Modine Manufacturing Comp	West Kingston	RI
Morgan Electric	Warwick	RI
Morra Electric Inc.	Johnston	RI
MPG Mechanical LLC	Charlestown	RI
Mr. Rooter Plumbing	Warwick	RI
MTG Heating	Pawtucket	RI
Multi State Restoration Inc.	North Providence	RI
Mustrocinque and Sons Plumbing and Heating LLC	Newport	RI
Mutual Engineering Service Company	Warwick	RI
Nasons Heating Cooling Sheet Metal	Middletown	RI
National Refrigeration Inc.	Warwick	RI
NDS Plumbing and Heating	Pawtucket	RI
New England Insulation	Woonsocket	RI
New England Plumbing Heating and Air LLC	Greenville	RI
Newport Electric	Portsmouth	RI
Newport Plumbing and Heating Gas Company	Portsmouth	RI
Nexgen Mechanical Inc.	Cranston	RI
NGB Electric	Smithfield	RI
Nicholas Fizzano	Ashaway	RI
Nolin Electric Incorporated	Providence	RI
North Atlantic Heating Inc.	Coventry	RI
Northeast Contracting	Cumberland	RI
Northeast Electrical Distributors	Cumberland	RI
Northeast Energy	Lincoln	RI
Northeast Heating and Cooling	North Scituate	RI
Northern Energy Services Inc.	Providence	RI
Northern Power Electrical Services	North Scituate	RI
Nouel Contractor Services	Providence	RI
O.A. Pagnozzi and Sons Inc.	Smithfield	RI
Ocean State Electric	Johnston	RI
Oceanline Combustion Service Inc.	Pawtucket	RI
Old Tyme Electric, Inc.	Pawtucket	RI
O'Neil Electric Company	Warwick	RI
Optimal Energy	Providence	RI
P & D Plumbing	Providence	RI
P & S Electric Inc.	East Greenwich	RI
P Mandatini Inc.	Cranston	RI
Pal Electric	Exeter	RI
Parrella Electric	Providence	RI
Patrarca Plumbing and Heating	Warwick	RI

Patrick Bragg	Warwick	RI
Patriot Plumbing Inc.	Coventry	RI
Paul Del Bonis	Providence	RI
Paul Manfredo Electric	Warwick	RI
Paul Pinheiro	North Providence	RI
Paul Scotto Electrical	Portsmouth	RI
Payne & Son Electrical Services	Foster	RI
PC Construction	Cranston	RI
PECI	Portsmouth	RI
Pellegrino Plumbing and Heating	Westerly	RI
Pelletier and Son Plumbing and Heating Inc.	North Kingstown	RI
Pemlico Plumbing	Warwick	RI
Percivalle Electric Inc.	Warwick	RI
Perez Plumbing and Heating LLC	Cranston	RI
Peter Bibby	Providence	RI
Petes Plumbing Inc.	North Smithfield	RI
Petrarca Plumbing and Heating	Warwick	RI
Petro Heating and Air Conditioning Services	East Greenwich	RI
Petronelli Plumbing and Heating	Cranston	RI
Phil Paul Plumbing and Heating	North Smithfield	RI
Philips Precision Plumbing LLC	Greene	RI
Phillco Electric	Central Falls	RI
Phillip J Bolster Plumbing and Heating	Wakefield	RI
Phillips Plumbing and Mechanical Inc.	Cranston	RI
Phil's Heating and Air Conditioning	Westerly	RI
Pickles Plumbing and Heating LLC	Mapleville	RI
Pinnacle Plumbing and Heating	Greenville	RI
Pipe Fixer	Coventry	RI
Plumb Perfection	Johnston	RI
Plumber Pros Inc.	Coventry	RI
Plumbing and Heating Solutions LLC	East Greenwich	RI
Polar Air	Wakefield	RI
Polaris Plumbing and Heating Inc.	Johnston	RI
Portland Group	Providence	RI
Potvin Enterprises Inc.	Warwick	RI
Power Trip Electric Inc.	Hope	RI
Pratt Plumbing and Heating LLC	Harrisville	RI
Precision Power	Wyoming	RI
Preferred Heat Inc.	Providence	RI
Premair HVAC	Warwick	RI
Premier Heating and Cooling	Lincoln	RI
Prince Noah HVAC	Central Falls	RI

Priority Plumbing and Heating Inc.	Providence	RI
Prism Consulting Inc.	Providence	RI
Pro Plumbing of Rhode Island	West Warwick	RI
Professional Services	Lincoln	RI
Providence Electric Inc.	Chepachet	RI
Providence Mechanical Services LLC	Smithfield	RI
R & M Electric Inc.	Coventry	RI
R. Vento & Son Electric	Johnston	RI
R.B. Queern Company Inc.	Portsmouth	RI
R.E. Coogan Heating Inc.	Warwick	RI
R.E.M. Electric, Inc.	Jamestown	RI
R.W. Bruno Heating & Cooling	Lincoln	RI
Ralph Devivo Plumbing and Heating	North Smithfield	RI
Ralph E Geiselman Plumbing and Heating	Pawtucket	RI
Ralph Ferra Plumbing	North Smithfield	RI
Randy Pomeroy	Pascoag	RI
Ray Christopher	Foster	RI
Raymond J Reinsant Plumbing and Heating	Lincoln	RI
Raz Heating and Plumbing Services	Foster	RI
RB Homes	Johnston	RI
RC Plumbing and Heating	North Providence	RI
RCS Energy Services	Providence	RI
Reddy Piping Concepts Inc.	Cranston	RI
Regan Heating & Air Conditioning Inc.	Providence	RI
Reichert and Sons Fuel Oil Inc.	Chepachet	RI
Reinhold Plumbing and Heating Inc.	Johnston	RI
Reliable Plumbing and Mechanical Inc.	North Providence	RI
Reliant Electric	Cranston	RI
Renaissance Sheet Metal LLC	Cranston	RI
Renewable Plumbing Heating Solar and Air	East Providence	RI
Resendes Heating Service LLC	Coventry	RI
Resource Construction Inc.	Jamestown	RI
Restivos Heating and Air Conditioning	Johnston	RI
Rexel Energy Solutions (Munro Distributing)	Cranston	RI
Rhode Island Electrical Rooter and Plumbing	Providence	RI
Rhode Island HVAC	Pawtucket	RI
Rhode Island Insulation	Hope	RI
Rhode Island Interfaith Power and Light	North Kingstown	RI
Rhode Island Plumbing and Heating Inc.	Cumberland	RI
Rhody Electric	Warwick	RI
Rhody Plumbing	Smithfield	RI
RI Electric LLC	Providence	RI

Richard Dufresne	Mapleville	RI
Richard Gayer Electric	Bristol	RI
Richard Migliori	Newport	RI
Richard R Lavey	Warren	RI
Ridge Property LLC	Cumberland	RI
Right View Electric. Inc.	East Providence	RI
Rise Engineering	Cranston	RI
Ritacco Electric LLC	Westerly	RI
RMS Ruggieri and Sons Mechanical LLC	Richmond	RI
RN Electric	North Providence	RI
Robert Colaluca Plumbing	Johnston	RI
Robert Dionne Electrical Contractor	Providence	RI
Robert Rachiele Electrician	Coventry	RI
Robert Schnaible	Hope	RI
Roberts Electric	Pawtucket	RI
Rock House Construction LLC	Johnston	RI
Roger Adam Electrician	Manville	RI
Roland and Son Building and Remodeling	Saunderstown	RI
Roland M Belanger Plumbing and Heating	Pascoag	RI
Ron Manish	Scituate	RI
Ronald Lima	Rumford	RI
Ronald Stamp	Johnston	RI
Rooter Man Plumbing Heating Drains	Cumberland	RI
Rossi Electric Company	Cranston	RI
RSC Plumbing LLC	Exeter	RI
RSM Electric	Greenville	RI
RST Mechanical	North Kingstown	RI
Rumford Mechanical Systems LLC	Rumford	RI
Russ Lembo Electrician	Johnston	RI
Russell Barron Plumbing	Cranston	RI
Ryan Balme Electric	Chepachet	RI
Ryan Electric Construction	Warwick	RI
S & C Boilers	West Warwick	RI
S & P Machine	West Warwick	RI
S & S Electric	Chepachet	RI
S.B. Carbone Plumbing and Heating Company Inc.	Cranston	RI
Sakonnet Plumbing and Heating Inc.	Little Compton	RI
Sal Manzi and Son Plumbing and Heating Inc.	Cranston	RI
Sam Bliven Jr Plumbing & Heating Inc.	Westerly	RI
Sanford Electric	Bristol	RI
Santoro Oil Company Inc.	Providence	RI
Sargent Plumbing	North Kingstown	RI

Sasa Mechanical Contractors Inc.	Johnston	RI
Satti Construction	Lincoln	RI
Savard Oil Company Inc.	East Providence	RI
Schwegler and Sons Plumbing and Heating Inc.	North Smithfield	RI
Scott Gatta Electric	Johnston	RI
Seddon Electric	Rumford	RI
Seekonk Supply Inc.	Providence	RI
Seminole Development	Lincoln	RI
Sensible Heating and Air Conditioning LLC	Hope Valley	RI
Sergio Alves	Central Falls	RI
Shamrock Electric	Middletown	RI
Sheridan Electric Inc.	Warwick	RI
Siemens Industry	Cranston	RI
Sine Plumbing and Heating Company Inc.	East Providence	RI
Sizemore Plumbing and Heating	Johnston	RI
Small'S Plumbing Inc.	Woonsocket	RI
SMC Mechanical	East Providence	RI
Smithfield Plumbing & Heating Supply Company	Greenville	RI
Sosa & Son Heating Air Conditioning & Refrigeration	Woonsocket	RI
Sound Building Corporation	Portsmouth	RI
Sousa Electric	Warwick	RI
South County Community Action	North Kingstown	RI
South Shore Electrical Contractors	Wakefield	RI
Spencer's Plumbing	North Kingstown	RI
SPL Electrical Corporation	North Smithfield	RI
St Angelo Plumbing	Barrington	RI
Standish Heating and Air Conditioning	Coventry	RI
Startrak Studios Inc.	Warwick	RI
State of Rhode Island	Providence	RI
Statewide Insulation	North Smithfield	RI
Statewide Plumbing and Heating Co Inc.	Cranston	RI
Stedman & Kazounis Plumbing and Heating	Charlestown	RI
Stem Electrical	Warwick	RI
Stephen Andrea Fire & Electric, LLC	Coventry	RI
Stephen Larochelle	Cumberland	RI
Sterling Mechanical Services	Greene	RI
Steve Dupre Plumbing	Pawtucket	RI
Steven Dubois Inc.	Bradford	RI
Steven Maymon	Warwick	RI
Sturbridge Home Builders Inc.	Warwick	RI
Suburban Heating and Cooling	Tiverton	RI
Summit Electrical Contractors Inc.	Lincoln	RI

Sunrise Plumbing and Heating	Johnston	RI
Sunshine Fuels and Energy Services Inc.	Bristol	RI
Superior Comfort Inc.	Bristol	RI
Superior Electric	Providence	RI
Superior Insulation	Narragansett	RI
Superior Plumbing and Heating	Cranston	RI
Supply New England	Pawtucket	RI
Sure Fire Heating	West Greenwich	RI
Sustainable Energy Solutions	Providence	RI
SW & Sons Plumbing & Heating	Johnston	RI
Swap Inc.	Providence	RI
Sylvania Lighting Services	Johnston	RI
Sylvester Sheet Metal Inc.	West Warwick	RI
Symmes Maini & McKee Associates	Providence	RI
T & J Heating Air Conditioning and Plumbing Inc.	Bellingham	RI
T & T Plumbing and Heating Inc.	Hope Valley	RI
T Gomes Heating and Cooling	Providence	RI
T. Murphy Electric	Cranston	RI
T.A. Gardiner Plumbing & Heating Inc.	Bristol	RI
Tebano Electric	Bristol	RI
Tebo Electric Inc.	Woonsocket	RI
Temptec Mechanical	Providence	RI
TF Electric, LLC	East Greenwich	RI
The Farm Barlow Heating LLC	Warwick	RI
The Metalworks Corporation	Tiverton	RI
The Plumber Company LP	Cranston	RI
Thermal Energy Inc.	Cranston	RI
Therrien Mechanical Systems	Lincoln	RI
Thibault Plumbing and Heating Inc.	Cranston	RI
Thielsch Engineering	Cranston	RI
Thomas McGee Plumbing and Heating	North Smithfield	RI
TJ Billington & Son	Warwick	RI
TJ Homebuilders, Inc.	Exeter	RI
Todd Wakeman	West Greenwich	RI
Tom Peters Plumbing and Heating Inc.	Portsmouth	RI
Tom Whitaker	Newport	RI
Toms Plumbing LLC	Manville	RI
Toner Electric Co	Middletown	RI
Tops Electric Supply	Providence	RI
Total Comfort Heating and Cooling Inc.	Lincoln	RI
Total Construction Services Inc.	Providence	RI
Total Control HVAC LLC	Cranston	RI

Total Home Care	Warwick	RI
TR Electric Inc.	Ashaway	RI
Travers Plumbing and Heating Incorporated	Portsmouth	RI
Tri-Town Community Action	North Providence	RI
Truth Box Inc.	Providence	RI
Tuma Insulations	Warwick	RI
Tyfas and Co. Inc.	Warren	RI
UG Nasons Inc.	Middletown	RI
United Burner Services Inc.	West Warwick	RI
United Mechanical Inc.	Cranston	RI
V. Bevilacqua & Son, Inc.	Smithfield	RI
Valcourt Heating Inc.	Tiverton	RI
Valley Heating and Cooling Inc.	Hope Valley	RI
Valmer D Montoya Air Heating and Cooling Inc.	Central Falls	RI
Van's Electric Inc.	Bristol	RI
Vaughn Oil Company Inc.	Smithfield	RI
Venancio Brothers Plumbing and Heating	Middletown	RI
Vicmir & Sons Heating and Air Conditioning Controls	Riverside	RI
Victory Heating and Air Conditioning Company Inc.	Bellingham	RI
Viking Electric Inc.	Providence	RI
Vincent Heating & Air Inc.	Cranston	RI
Vintage Plumbing	Riverside	RI
Vivona Plumbing and Heating Inc.	Portsmouth	RI
W.E. Hill Plumbing and Heating Inc.	Bristol	RI
W.W. Grainger, Inc.	Warwick	RI
Wakefield Heating Service LLC	Wakefield	RI
Wakefield Plumbing LLC	Newport	RI
Walco Electric Company	Providence	RI
Waldo Plumbing and Heating LLC	Lincoln	RI
Walsh Electric	Bristol	RI
Warroom Document Solution	Providence	RI
Waterworks Plumbing and Services LLC	Johnston	RI
Wesco Oil & Propane Inc.	Esmond	RI
West Bay Community Action Partnership	Warwick	RI
West Bay Copy LLC	Kingston	RI
Wicked Watts LLC	Providence	RI
Wickford Appliance and Lighting Inc.	Pawtucket	RI
William Calia Electric	Johnston	RI
William Carceri	Cranston	RI
William J Riley Plumbing and Heating	Warwick	RI
William Merritt Plumbing and Heating LLC	North Kingstown	RI
William S Ferrara	East Providence	RI

WJM Property Consulting Inc.	West Warwick	RI
Woods Heating Service	East Providence	RI
Wordell Heating and Cooling LLC	Little Compton	RI
Wyman & Sons Electric Company Inc.	Warwick	RI
Zanella Plumbing and Heating Inc.	Westerly	RI
Zap's Electrical	North Scituate	RI
Zawadzki Plumbing and Heating Inc.	Warwick	RI
Zompa Plumbing and Heating	Barrington	RI
Blackhawk Engagement Solutions (Parago)	Lewisville	TX
Compressed Air Challenge	Alexandria	VA
Opower Inc.	Arlington	VA
Kelliher Samets Volk	Burlington	VT
Vermont Energy Investment Corporation	Burlington	VT
Evoworx Inc.	Seattle	WA
New Buildings Institute Inc.	White Salmon	WA
Illume Advising LLC	Verona	WI

Massachusetts Special and Cross-Cutting Research Area: Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts (NEIs) Study

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Prepared by:

Beth A. Hawkins, Three³, Inc.
Dr. Bruce E. Tonn, Three³, Inc.
Erin M. Rose, Three³, Inc.
Greg Clendenning, NMR Group
Lauren Abraham, NMR Group

Prepared for:
Massachusetts Program Administrators

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Executive Summary

Weatherization can produce health-related non-energy benefits directly by changing the physical condition of homes. For example, improving the thermal performance of the building envelope, which at minimum increases comfort, also reduces thermal stress experienced by occupants. Additionally, installation of a comprehensive set of weatherization measures can synergistically reduce a plethora of asthma triggers. Weatherization also increases safety through the testing of carbon monoxide (CO) in homes with combustion appliances, the repair and replacement of gas furnaces, and the installation of CO monitors and smoke detectors. Improved health and energy cost savings, in turn, can reduce missed days of work, increase productivity at home, and lead to household budget benefits that then are invested to produce additional household and societal benefits.

In 2011, the NMR Group[1] conducted an evaluation study of non-energy impacts (NEIs) attributable to the Massachusetts (MA) Program Administrators' (PAs') residential and low-income (LI) programs that examined a number of health and safety-related benefits to LI residents.[2] In 2015, an evaluation of the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) was completed that included the assessment and monetization of twelve health and household-related impacts attributable to the weatherization of income-eligible single-family (SF) homes, at a national level.[3,4] Three³ (pronounced Threecubed) research staff, under the auspices of Oak Ridge National Laboratory, conducted this DOE funded evaluation. In order to complement NMR's findings, the MA PAs contracted Three³ to assess and monetize a sub-set of these NEIs experienced by recipients of energy efficiency services residing in income-eligible households in the state of MA. The subset of eight NEIs was selected based on their estimable, direct impact on the household, which was of most interest to the PAs; whereas, the remaining four estimated only societal impacts (i.e., reduced need for food assistance, improvement in prescription adherence, increased productivity at work due to improved sleep, reduction in low-birth weight babies from heat or eat dilemma). The subset of NEIs selected for Three³'s MA LI SF NEI study are as follows:

1) reduced asthma (lower medical costs);
2) reduced cold-related thermal stress (lower medical costs and fewer deaths);
3) reduced heat-related thermal stress (lower medical costs and fewer deaths);
4) reduced missed days at work (reduction in lost income);
5) reduced use of short-term, high interest loans (lower interest payments and loan fees);
6) increased home productivity due to improvements in sleep (higher productivity for housekeeping);
7) reduced carbon monoxide (CO) poisoning (lower medical costs and fewer deaths); and
8) reduced home fires (fewer fire-related injuries, deaths, and property damage).

The national WAP NEI evaluation research was utilized as the foundation for the MA LI SF NEI study; although, in order to conduct a state-level analysis, inputs needed to be context sensitive.

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[1] http://www.nmrgroupinc.com/

[2] NMR. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for Massachusetts Program Administrators. (See: http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf)

[3] A complete report presenting findings from this component of the WAP evaluation was published in 2014 and can be found at www.threecubed.org.

[4] A complete description of the methodology is found in: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.

Slight modifications were made to the research method and several inputs were revised based on updated or context specific data (modifications are discussed in more detail in Section 2.3). Each NEI required a customized approach; however, several adopted a similar framework and, when appropriate, utilized uniform inputs.

The PAs tasked NMR to review the methodology utilized for the national WAP evaluation, as well as the findings from the MA LI SF NEI study presented in this report. The purpose of this task was to determine the extent to which the NEIs quantified in this WAP-based evaluation overlap with, augment, or supersede the health- and safety-related NEIs previously examined and/or currently claimed by the PAs, and to develop recommendations for integrating the results.

Underpinning the methodology utilized to estimate the NEIs attributable to the national WAP was a pre-tested, national Occupant Survey of a random and representative sample of weatherized single-family[5] homes pre- and post-weatherization, along with a comparison group of homes. The Occupant Survey was administered in two phases.[6] In phase 1, the survey was administered just prior to the energy audits completed in the treatment group households. The second phase was implemented post-weatherization, approximately 18 months later. In addition, a group of homes that had already been weatherized one year before the treatment group received weatherization services was surveyed during phase 1; this group of homes served as a post-weatherization comparison group.

During the data analysis design phase, the issue of whether sample sizes were large enough to capture rare events was encountered. For example, the Occupant Survey asked questions about the incidence of fires and CO poisoning pre- and post-weatherization. The responses indicated that both were very rare given the sample size, and national data supports these conclusions. However, preventing fires and CO poisoning are policy relevant and important NEIs of weatherization; therefore, we believe that estimating the monetized benefits of reducing fires and CO poisoning are worthwhile given that deaths could be prevented. So, in these two instances, data collected through the national evaluation on weatherization measures installed (e.g., various measures that map specifically to fire ignition risks or serve as fire suppressors), national Occupant Survey responses for CO monitors installed that may reduce the incidence of CO poisoning, along with secondary data were relied upon to anchor the methodologies.

Descriptive statistics generated from these surveys demonstrated post-weatherization benefits. For several of the NEIs, the differences between the treatment groups pre- and post-weatherization were statistically significant. Many differences between the pre-weatherization treatment group and the post-weatherization comparison group were also statistically significant.

Additionally, these findings were augmented by anecdotal evidence offered by the human stories shared by the weatherization agencies and by recipients of the programs themselves. Ultimately, these benefits were analyzed from multiple angles. Triangulation as a research method (i.e., arriving at conclusions by using multiple sources of information) is common within the social sciences. Because the benefits selected for analysis were approached in this way, the Three[3] researchers were able to confidently monetize changes in occurrences even if they did not

[5] Single-family homes surveyed included mobile homes and small multifamily buildings consisting of between two and four units.
[6] For detailed information on the national Occupant Survey, refer to the Occupant Survey Report: Carroll, D., Berger, J., Miller, C., and Driscoll, C. 2014. National Weatherization Assistance Program Impact Evaluation - Baseline Occupant Survey: Assessment of Client Status and Needs. ORNL/TM- 2015/22, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

achieve statistical significance for the reasons explained above. A national panel of experts reviewed all methodologies and assumptions—the panel did not question the validity of any of the NEIs nor were the findings dismissed as inconsiderable as there was a clear indication of health improvements.

For the national WAP evaluation, the estimated NEI values were presented on a dollar per weatherized unit basis, broken down by both societal and household cost benefit categories based on health care coverage:

- For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs was categorized as a societal benefit;
- For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (i.e., copayments, deductibles) were categorized as a household benefit; and
- For individuals/occupants that are "uninsured," all of the avoided medical costs was categorized as a household benefit.[7]

With respect to the cost benefit of avoided deaths, if applicable, two separate values were presented: one with the Value of Statistical Life (VSL), or the benefit of avoided deaths, included and one without.[8] Based on discussions with reviewers, it was decided that the benefit of avoided deaths, or VSL, would be considered a societal benefit. Also, the present value (PV) of all benefits were estimated over a twenty-year time horizon reflecting the persistence of the measure.[9] Lastly, as recommended by the national panel of experts, estimates were categorized and presented in three tiers. Tier 1 included estimates based on observed monetizable outcomes attributable to weatherization and highly reliable cost data. Tier 2 and 3 estimates were established to have underlying sound methodologies but may have lacked direct observations of improved health or well-being and/or required relatively more assumptions.

The presentation of estimated NEI values for the MA LI NEI study are similar to the national WAP evaluation in that values are presented on a per weatherized unit basis, broken down by their household and societal benefit components, a PV estimate of the benefits is provided, and estimates are presented in three tiers. Lastly, VSL associated with avoided deaths (except for firefighters) was applied as a household benefit rather than a societal benefit (See Section 2.3.1 for a detailed discussion on avoided death benefits and VSL).[10]

[7] Except for asthma as a chronic health condition, where 7% of the total avoided medical costs are OOP costs for uninsured individuals and applied as a household benefit, with the remaining medical costs applied as a societal benefit.

[8] Value of human life, or as economists refer to it as, the Value of Statistical Life (VSL), is a measure used to compare regulatory costs to benefits. At the time of the WAP evaluations, the U.S. government agencies were using values ranging from $5-9 million in regulatory cost-benefit analysis. The WAP National Evaluation used a conservative VSL of $6 million (2000 dollars) adjusted for inflation to $7.5 million in 2008 dollars.

[9] With the exception of the non-energy impact of installing CO monitors, where present value was calculated over a more conservative 5-year period as the lifespan of CO monitors generally remains effective for an average of five years.

[10] The VSL of $7.5M used in the national WAP evaluation was updated to $9.6M, a 2016 VSL recommended by the U.S. Department of Transportation (DOT). In an effort to utilize a context-sensitive VSL, a thorough scan of MA government agencies' usage of VSL's for cost-benefit analyses was conducted. The DOT's Office of General Council updates this VSL annually and releases an annually revised memo entitled: *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses.*

Table E.1 presents the annual estimated values of the monetized NEIs selected for the MA LI SF NEI study, per weatherized unit—for both societal and household benefit categories. The overall valuation results are driven quite strongly by the assertion that the program is saving lives; however, given the uncertainty surrounding the estimate of the number of deaths avoided, the household cost savings have been presented both with and without the avoided death benefit.

The main contributors to estimates presented in Table E.1 are: avoided deaths from thermal stress, CO poisoning, and home fires; avoided hospitalizations and emergency department (ED) visits related to these three areas as well as asthma-related symptoms; and disposable income gains from fewer missed days at work. Table E.2 provides the PV for the estimates presented in Table E.1. Table E.3 provides a breakdown of the avoided number of deaths, if any, and hospitalizations, ED visits, and physician office visits annually for each health-related NEI, per 1,000 units weatherized.

Table E.1. Estimated MA Low-Income Household and Societal NEIs Per Weatherized Unit both With and Without Avoided Death Benefit—Annual per Unit

NEI Value	Annual Per Unit Benefit*				
	Household	**Household W/O Avoided Death Benefit**	**Societal**	**Total**	**Total W/O Avoided Death Benefit**
Tier 1					
Reduced asthma symptoms	**$9.99**	$9.99	$322.01	**$332.00**	$332.00
Reduced cold-related thermal stress	**$463.21**	$4.67	$33.73	**$496.94**	$38.40
Reduced heat-related thermal stress	**$145.93**	$8.28	$27.00	**$172.93**	$35.28
Fewer missed days at work	**$149.45**	$149.45	$37.36	**$186.81**	$186.81
Tier 2					
Reduced use of short-term, high-interest loans	**$4.72**	$4.72	$0	**$4.72**	$4.72
Reduced CO poisoning (5-year life)	**$36.98**	$0.25	$1.87	**$38.85**	$2.12
Tier 3					
Increased home productivity	**$37.75**	$37.75	$0	**$37.75**	$37.75
Reduced home fires	**$93.84**	$9.77	$17.87**	**$111.71**	$27.37**
Annual Total—per weatherized home	**$941.87**	**$224.88**	**$439.84**	**$1,381.71**	**$664.45**

*For CO poisoning, the annual NEI is to be applied over the 5-year life of the CO monitor. The remaining NEIs are to be applied annually over the life of the relevant measure (e.g., 20 years for weatherization).
**For home fires, the avoided injuries and deaths to firefighters are categorized as a societal benefit.

Table E.2. Estimated MA Low-Income Household and Societal NEIs Per Weatherized Unit both With and Without Avoided Death Benefit— Per Unit at Present Value (20 Years at 0.44%)

NEI Value	PV (20 years) Per Unit Benefit				
	Household	Household W/O Avoided Death Benefit	Societal	Total	Total W/O Avoided Death Benefit
Tier 1					
Reduced asthma symptoms	**$190.92**	$190.92	6,151.96	**$6,342.88**	$6,342.88
Reduced cold-related thermal stress	**$8,849.71**	$89.30	$644.47	**$9,494.18**	$733.77
Reduced heat-related thermal stress	**$2,787.95**	$158.19	$515.86	**$3,303.81**	$674.05
Fewer missed days at work	**$2,855.21**	$2,855.21	$713.80	**$3,569.01**	$3,569.01
Tier 2					
Reduced use of short-term, high-interest loans	**$90.18**	$90.18	$0	**$90.18**	$90.18
Reduced CO poisoning (5 years)*	**$183.30**	$1.25	$9.28	**$192.58**	$10.53
Tier 3					
Increased home productivity	**$721.26**	$721.26	$0	**$721.26**	$721.26
Reduced home fires	**$1,792.84**	$186.68	$341.39**	**$2,134.23**	$522.96**
PV Total—per weatherized home	**$17,471.37**	**$4,292.99**	**$8,376.76**	**$25,848.13**	**$12,664.64**

*For CO poisoning, PV is estimated for 5 years
** For home fires, the avoided injuries and deaths to firefighters are categorized as a societal benefit.

Table E.3. Number of Avoided Deaths, Hospitalizations, ED Visits, and Physician Office Visits Annually for Each Health-Related NEI, Per 1000 Units Weatherized

NEI	Deaths	Hospitalizations	ED Visits	Physician Office Visits
Asthma	-	9.9 (adult) 4.2 (child)	54.6	-
Cold-related Thermal Stress	0.05	1.9	7.6	9.5
Heat-related Thermal Stress	0.01	1.1	23.6	3.2
CO Poisoning	0.004	0.07	0.47	-
Fire Injury	0.0087	0.013	0.4	0.25

Key Limitations and Sources of Uncertainty

As discussed throughout this report, Three[3]'s NEI estimates are subject to the following key limitations and sources of uncertainty:

- Because of the design of the national Occupant Survey for which the results are based, the MA-specific results generally apply only to occupants of and measures implemented in low-income single-family homes. These include housing units in small multifamily buildings consisting of between two and four units in total, which is consistent with the PAs' classification of single-family homes in their programs. To the extent possible and at their discretion, however, the PAs may be able to apply the single-family NEIs estimated herein to larger multifamily complexes consisting of "single-family like" units.
- There is considerable uncertainty in the VSL, which ranged from $5 million to $9 million at the time of the national WAP evaluation. An updated value of $9.6 million (2015 dollars) recommended by the USDOT is being applied. A more context sensitive VSL could not be found.
- Except for asthma and reduced CO poisoning, only one (1) occupant per household is assumed to be affected for each NEI.
- The prevalence of asthma in MA could be higher (e.g., larger percentage of communities of color), and asthma analysis does not account for multiple re-admittances.
- For thermal stress, extreme winter and summer weather events that could occur in any given year are unaccounted for. In addition, national (not MA) incidence rates for treatment type and death from thermal stress are applied.
- Only one (1) short-term, high-interest loan per year per household is assumed to be avoided.
- It is assumed that weatherization only reduces the probability of fire to the average probability of fire.[11]

NMR's Recommendations for Integrating and Applying the Results of Three[3]'s MA LI SF NEI Study

Following are NMR's recommendations for integrating the results of Three[3]'s MA LI SF NEI study presented in this report into the NEI estimates currently used by the MA PAs (see Section 10.0):

- **Reduced Asthma**—Replace the currently used Health Related NEIs estimate of $19 per year derived from the 2011 NMR study with the asthma NEI value of $9.99 presented in this report (as well as the other health-related NEIs included in this report: reduced thermal stress and fewer missed days at work)
- **Reduced Thermal Stress (both Hot and Cold-Related)**—Replace the currently used Health Related NEI estimate of $19 per year derived from the 2011 NMR study with the cold- and heat-related thermal stress NEI values of $463.21 and $145.93, respectively, presented in this report (as well as the other health-related NEIs included in this report: reduced asthma and fewer missed days at work).
- **Fewer Missed Days at Work**—Replace the currently used Health Related NEIs value estimate of $19 per year derived from the 2011 NMR study with the missed days of work due to illness NEI value of $149.45 presented in this report (as well as the other health-related NEIs included in this report: reduced asthma and fewer missed days at work).
- **Reduced Use of Short-Term, High Interest Loans**—NMR does not recommend counting the NEI value produced by Three[3] in this report as it is not likely a benefit in the

[11] The WAP study evaluated the reduction in fire risk from a wide range of measures, and the $57.48 portion of the total estimated NEI is attributable to measures currently installed by the PAs programs, including the safety inspection, replacement, and/or installation of smoke detectors.

current TRC context, though it could be considered if a different cost were used in the future. Additionally, the PAs could consider further examination of a potential multiplier effect to determine if the benefits accruing to low-income households from bill savings are larger than the corresponding cost in the form of lost PA revenues.

- **Increased Productivity At Home**—The WAP study theorized that the NEI of *increased productivity at home* is attributable to making the weatherized homes more comfortable and conducive to better sleep and therefore likely overlaps with the NEI of improved comfort currently claimed by the PAs.[12] Because of the potential overlap, NMR recommends counting half the NEI value for *increased productivity at home* (to an adjusted value of $18.88).
- **Reduced CO poisoning**—Replace the CO poisoning portion ($6.38 per year) of the Improved Safety NEI derived from the 2011 NMR study with the reduced CO NEI value of $183.30 (one-time PV given the shorter 5-year life of CO detectors) presented in this report.
- **Reduced Risk of Fire and Fire-Related Property Damage**—Replace the fire-safety related NEI of $38.67 per year (for avoided fire deaths, injury, and property damage) currently claimed by the PAs with the fire-safety related NEI value of $57.48 presented in this report.[13]

The substantial increase in the health-related NEIs are largely attribubable to thermal stress NEI and reduced missed days from work. The increase in the thermal stress NEI is principally attributable to the avoided deaths by reducing the chance of an individual being subjected to dangerously cold or hot temperatures (see section 4.0 for an overview of the risks of thermal stress). The risks of thermal stress, including heat and cold-related mortality, are very real and substantial. A recent National Health Statistics Report estimated 2,000 weather related deaths per year in the US from 2006 to 2010 (during the WAP study period) (Berko et al. 2014), with about 31% of these deaths attributed to exposure to heat-related causes and 63% attributed to exposure to excessive cold. The report includes estimates by region, estimating 307 heat and cold related deaths per year in the northeast region. Asuming the deaths are roughly proportionate to the population in each state, there are an estimated 36 cold and heat related deaths per year in Massachusetts, 29 of which were cold-related and eight of which are heat-related (See section 10 for more details).

The substantial increase in the reduced missed days from work NEI is attributable to the WAP study being able to estimate the number of missed days from work (for health-related reasons) and in turn estimate lost wages whereas the 2011 NMR study relied on a single, self-reported estimate of health impacts.

The evaluation team estimated NEIs at the measure level by following the procedures used in the 2011 NMR study. With the exception of CO and Fire, the team assigned a portion of a given NEI value to relevant individual measure based on the average energy bill savings for which the measure was responsible in the 2011 NMR study. The health-related NEIs are apportioned as follows: air sealing (29.9%), duct sealing (0.7%), heating system (27.7%), insulation (25.1%),

[12] The WAP study found evidence of overlap between comfort and sleep through their household survey, finding that warmer, less drafty homes were correlated with better sleep. In addition, the study found that bad sleep is positively correlated with bad physical health days, suggesting potential overlap between the WAP health NEIs and increased productivity (as increased productivity is monetized through reducing productivity losses due to sleep problems).

[13] The WAP study evaluated the reduction in fire risk from a wide range of measures, and the $57.48 portion of the total estimated NEI is attributable to measures currently installed by the PAs programs, including the safety inspection, replacement, and/or installation of smoke detectors.

pipe wrap (5.5%), service to heating or cooling system (6.1%), programmable thermostat (4.8%) and window replacement (0.08%). The NEI for CO is based on CO monitor installation and therefore the entire value is applied to projects that include safety reviews and installation of CO monitors (see Table E.4 for the apportionment of NEIs by measure as well as a comparison of the 2011 NMR and 2016 Three[3] values for each main NEI category). Finally, the analysis in this report is able to estimate the reduction in fire risk on a measure-by-measure basis (See Section 9.0 for more details).

Table E.4. Apportionment of Household NEI Values to Individual Measures

		NEI Category and Recommended Values ($ per unit)											
		Reduced asthma symptoms	Reduced cold-related thermal stress	Reduced heat-related thermal stress	Fewer missed days at work	Total Health Benefits	Increased home productivity	Total Thermal Comfort (1)	Reduced CO Poisoning	Reduced Home Fires		Total Improved Safety	
	2011 NMR Value					**$19.00**		**$101.00**	$6.38 (Annual) (3)		$38.67 (3)	**$45.05**	
	Recommended Value (Three³ 2016)	$9.99	$463.21	$145.93	$149.45	**$768.58**	$18.88	**$119.88**	$183.30 (One-Time)		$93.84	**$183.30 One Time for CO Detectors + $57.48 Annual for Fire and Smoke Detectors**	
Measure	**Percent of Bill Savings used to Apportion Health and Thermal Comfort NEIs (2)**	Annual	Annual	Annual	Annual	**Annual**	Annual	**Annual**	One-Time	Estimated Risk Reduction (Three³ 2016)	Annual	**Annual**	
Aerator	0%	$0.00	$0.00	$0.00	$0.00	**$0.00**	$0.00	**$0.00**			$0.00	**$0.00**	
Air sealing	29.9%	$2.99	$138.66	$43.69	$44.74	**$230.08**	$5.65	**$35.89**		2.39%	$2.24	**$2.24**	
Appliance (refrigerators and freezers)	0%	$0.00	$0.00	$0.00	$0.00	**$0.00**	$0.00	**$0.00**		1.49%	$1.40	**$1.40**	
Door	0.005%	$0.00	$0.02	$0.01	$0.01	**$0.04**	$0.00	**$0.01**			$0.00	**$0.00**	
Duct sealing	0.7%	$0.07	$3.12	$0.98	$1.01	**$5.17**	$0.13	**$0.81**			$0.00	**$0.00**	
Heating system	27.7%	$2.77	$128.45	$40.47	$41.44	**$213.13**	$5.23	**$33.24**		20.11%	$18.87	**$18.87**	
Hot water system	0%	$0.00	$0.00	$0.00	$0.00	**$0.00**	$0.00	**$0.00**		4.73%	$4.44	**$4.44**	
Insulation	25.1%	$2.51	$116.41	$36.67	$37.56	**$193.15**	$4.74	**$30.13**		18.54%	$17.40	**$17.40**	
Lighting	0%	$0.00	$0.00	$0.00	$0.00	**$0.00**	$0.00	**$0.00**		2.84%	$2.67	**$2.67**	
Pipe wrap	5.5%	$0.55	$25.51	$8.04	$8.23	**$42.34**	$1.04	**$6.60**			$0.00	**$0.00**	
Service to heating or cooling system	6.1%	$0.61	$28.33	$8.93	$9.14	**$47.01**	$1.15	**$7.33**		2.87%	$2.69	**$2.69**	
Low flow showerhead	0%	$0.00	$0.00	$0.00	$0.00	**$0.00**	$0.00	**$0.00**			$0.00	**$0.00**	
Programmable thermostat	4.8%	$0.48	$22.34	$7.04	$7.21	**$37.07**	$0.91	**$5.78**			$0.00	**$0.00**	
Window	0.08%	$0.01	$0.36	$0.11	$0.12	**$0.60**	$0.01	**$0.09**		2.41%	$2.26	**$2.26**	
Total	**100%**	$9.99	$463.21	$145.93	$149.45	**$768.58**	$18.88	**$119.88**		55.38%	$51.97	**$51.97**	**Annual for Fire**
Smoke Detector Inspection/Replacement/Installation (3)	N/A									5.87%	$5.51	**$5.51**	**Annual for Smoke Detectors**
										61.25%	**$57.48**	**$57.48**	**Annual for Fire + Smoke Detectors**
CO Detector Inspection/Replacement/Installation (3)	N/A								$183.30			**$183.30**	**One-Time for CO Detectors**
												$36.98	(Annual for CO Detectors, 5 yrs)
									Other Measures to Which the Fire NEI can be Apportioned:				
									Electrical repair	16.55%	$15.53		
									Clothes dryer vent repair/replacement	11.56%	$10.85		
									Chimney repair	3.52%	$3.30		
									Fans repair/replacement	2.58%	$2.42		
									Ventilation	3.68%	$3.45		
									Gas	0.87%	$0.82		

Notes:

(1) The revised value reflects NMR's 2011 estimate of $101 for Thermal Comfort plus half of Three³'s estimate for Increased Home Productivity (one-half of $37.75, or $18.88) to account for potential overlap.

(2) With the exception of Reduced CO Poisoning and Reduced Home Fires, the NEIs are apportioned based on the relative percentages of the average bill savings across those measures that are relevant and applicable to each NEI, as analyzed and computed in the 2011 NMR study.

(3) NMR's 2011 estimate for the Improved Safety NEI ($45.05) was based on an analysis of avoided deaths from fire-related CO poisonings ($6.38) and avoided fire deaths, injuries, and property damage (totaling $38.67) due to heating system replacement only. On the other hand, Three³ is able to estimate the reduction in fire risk on a measure-by-measure basis, the results of which are reflected above. The revised NEI for CO Poisoning is based on CO monitor inspection/replacement/installation and therefore applies as a whole to each measure that involves the safety review, replacement and/or installation of CO monitors (i.e., is not apportioned among measures). The portion of the NEI for Reduced Home Fires attributable to smoke detectors ($5.51) is to be applied to each measure that involves the safety review, replacement and/or installation of smoke detectors.

Table E.5 presents a comparison of the 2011 NMR and 2016 Three^3 values for each main NEI category as well as for two key measures, Weatherization and Heating System Retrofit/Replacement, on both an annual and 20-year PV basis.

Table E.5. Comparison of 2016 Three^3 and 2011 NMR Estimates on Both Annual and (20 Year) Basis

	Annual		NPV (20 Yrs at 0.44%)	
	NMR 2011	**Three^3 2016 (1)**	**NMR 2011**	**Three^3 2016 (2)**
By NEI Category				
Health Benefits	$19.00	$768.58	$363.00	$14,683.78
Thermal Comfort	$101.00	$119.88	$1,929.61	$2,290.22
Improved Safety	$45.05	$94.46	$860.68	$1,281.40
By Key Measure				
Weatherization, electric or gas (3)	$10.46	$551.37	$199.84	$10,010.70
Heating System Retrofit/Replacement, electric or gas (4)	$50.32	$307.73	$961.37	$5,355.98

Notes:
(1) Three^3 2016 annual NEI estimate for Improved Safety, Weatherization, and Heating System Retrofit includes annual estimate for CO monitors of $38.67 (5-year life).
(2) Three^3 2016 NPV NEI estimate for Improved Safety, Weatherization, and Heating System Retrofit includes 5-yr (not 20-yr) NPV estimate for CO monitors of $183.30.
(3) Weatherization includes Health, Thermal Comfort, and Safety NEIs apportioned for air sealing, insulation, smoke detectors, and CO detectors.
(4) Heating System Retrofit/Replacement includes Health, Thermal Comfort, and Safety NEIs apportioned for heating system, smoke detectors, and CO detectors.

As shown in Table E.5 the differences between the two sets of results are substantial. The reasons for these substantial differences are as follows:

- The NMR estimates were based on the survey (post-weatherization only) respondents' ability to recognize and report health effects monetized by their willingness to pay for improved health and comfort *relative to their energy bill savings*, whereas the Three^3 estimates are based on the Occupant Survey respondents' self-reported changes in health and household status (as measured from pre- to post-weatherization with a comparison group) and monetized using a more robust set of secondary national and state medical incidence (e.g., applicable types of medical treatment sought) and cost (e.g., by type of insurance coverage and treatment) data.
- The sample size of the Occupant Survey was substantially larger, increasing Three^3's ability to detect rare events such as the need for urgent care and potential number of deaths due to thermal stress that could be avoided from weatherization.
- In the Three^3 analysis, the relatively few number of avoided deaths due to thermal stress, CO poisoning, and fire could therefore be monetized assuming a VSL of $9.6 million, which substantially increases the per unit value of the NEIs from the corresponding NMR estimate.

- NMR's survey questions referenced multiple health benefits collectively (colds, flus, asthma, and other chronic health conditions), whereas the Occupant Survey questions targeted each potential health benefit separately (asthma, thermal stress).
- NMR estimated the benefit of improved safety from reduced CO poisoning and fires due to a single measure only (heating system retrofit/replacement), whereas Three[3] estimated this benefit from a wider range of measures using a more robust set of secondary national and state CO and fire incidence data.

1.0 Introduction

A recent evaluation of the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) included the assessment and monetization of numerous health and household-related benefits attributable to the weatherization of low-income homes.[14,15] In 2015, the Massachusetts Program Administrators (herein refered to as PAs) contracted Three[3] to evaluate and monetize a sub-set of the health and safety-related non-energy impacts (NEIs) that had been evaluated in the national WAP evaluation. This study entailed the estimation of NEIs specific to the recipients of energy efficiency services residing in income-eligible households in Massachusetts (MA). The MA Low-Income (LI) NEI study included the estimation of the following NEIs:

1) reduced asthma (lower medical costs);
2) reduced cold-related thermal stress (lower medical costs and fewer deaths);
3) reduced heat-related thermal stress (lower medical costs and fewer deaths);
4) reduced missed days at work (reduction in lost income);
5) reduced use of short-term, high interest loans (lower interest payments and loan fees);
6) increased home productivity due to improvements in sleep (higher productivity for housekeeping);
7) reduced carbon monoxide (CO) poisoning (lower medical costs and fewer deaths); and
8) reduced home fires (fewer fire-related injuries, deaths, and property damage).

In 2011, the NMR Group[16] had conducted an evaluation study of NEIs attributable to the PAs' residential and low-income programs; that study examined a number of health and safety-related benefits to low-income residents.[17] The PAs are currently using some of the NEIs examined in the 2011 NMR study to claim benefits for applicable programs. The PAs tasked NMR to review the health and household-related benefits study conducted through the national WAP evaluation as well as Three[3]'s additional MA LI SF NEI study. The purpose of NMR's review was to determine to what extent the health and safety NEIs quantified in this WAP-based evaluation overlap with, augment, or supersede the health- and safety-related NEIs previously examined and/or currently claimed by the PAs, and to develop recommendations for integrating the results.[18]

Section 1.0 of this report provides an overview of the health and household-related NEIs component of the national WAP evaluation that was utilized as the foundation for the MA LI SF

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[14] Three[3] research staff, under the auspices of Oak Ridge National Laboratory, managed the national WAP evaluation. A complete report presenting findings from this component of the WAP evaluation was published in 2014 and can be found at www.threecubed.org.
[15] A complete description of the methodology is found in: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.
[16] http://www.nmrgroupinc.com/
[17] NMR. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for Massachusetts Program Administrators. (See: http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf)
[18] The Occupant Survey was administered to single family homes including mobile homes and housing units in small multifamily buildings consisting of between two and four units in total, which is consistent with the PAs' classification of single family homes in their programs. Application of NEI results presented in this report to large multifamily buildings is not recommended, given that the building science of large multifamily is unique and the measures installed can be quite different from those installed in single-family and mobile homes. To the extent possible and at their discretion, however, the PAs may be able to apply the single-family NEIs estimated herein to larger multifamily complexes that consist of single-family like units.

NEI study. Section 2.0 presents a description of preliminary processes and statistical analyses leading up to the monetization of the NEIs of weatherization as delivered in Massachusetts. Section 3.0 through 9.0 present the eight NEIs chosen for inclusion in the MA LI SF NEI study.[19] Each NEI section provides an overview of the NEI as it relates to weatherization; a brief summary of the methodology utilized in the national WAP evaluation; and a description of the analysis utilized by Three[3] for the MA LI SF NEI study followed by a discussion. Section 10.0 presents NMR's assessment of Three[3]'s analyses and provides recommendations for the PAs' consideration, on a case-by-case basis.

1.1 National WAP Evaluation

Underpinning the research for the national WAP evaluation was a national Occupant Survey of a random and representative sample of weatherized single-family[20] pre- and post-weatherization, along with a comparison group of homes. The Occupant Survey was administered in two phases.[21] In phase 1, the survey was administered to a sample of homes just prior to the energy audits completed in the treatment group households (during calendar year (CY) 2011) (referred to as the Pre-Weatherization Treatment group). The second phase was implemented post-weatherization, approximately 18 months later (during CY 2013) (Post-Weatherization Treatment group). A comparison of these results provides direct insights into the impacts of weatherization because they involved the same group of households surveyed at different points in time.

A group of homes that had already been weatherized one year before the treatment group received weatherization services (Post-Weatherization Comparison) was also surveyed during phase 1. Comparisons between the Pre-Weatherization Treatment and Post-Weatherization Comparison groups also provide useful insights since the data for both groups were collected in the same time period.

For many of the NEIs evaluated through the national WAP evaluation, the differences between the treatment groups pre- to post-weatherization were statistically significant. Many differences between the Pre-Weatherization Treatment group and the Post-Weatherization Comparison group were also statistically significant.

Descriptive statistics generated from these surveys suggest the following post-weatherization benefits:

- The physical condition of homes is improved making the homes more livable;
- Respondents experience fewer 'bad' physical, mental health, and sleep/rest days;
- Respondents and other household members suffer fewer persistent colds and headaches;
- There are fewer instances of doctor and emergency department visits, and hospitalizations related to asthma and thermal stress;

[19] Section 4.0, Reduced Thermal Stress on Occupants, combines two NEIs, cold and heat-related thermal stress.
[20] Single-family homes surveyed included mobile homes and small multifamily buildings consisting of between two and four units..
[21] For detailed information on the national Occupant Survey, refer to the Occupant Survey Report: Carroll, D., Berger, J., Miller, C., and Driscoll, C. 2014. National Weatherization Assistance Program Impact Evaluation - Baseline Occupant Survey: Assessment of Client Status and Needs. ORNL/TM- 2015/22, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

- Households are better able to pay energy and medical bills;
- Households are better able to pay for food; and
- Household use of two kinds of short-term, high interest loans (tax refunds and pawn shops) decreases.

To estimate overall program cost effectiveness, it is important to monetize both the energy costs savings and the non-energy benefits attributable to the program. Survey results, estimates of weatherization measures installed (e.g., CO monitors), secondary databases containing national estimates of healthcare costs, and other secondary data and literature were used to monetize these twelve health and household related co-benefits of DOE's WAP:

- Reduced Carbon Monoxide Poisonings
- Reduced Home Fires
- Reduced Thermal Stress on Occupants From Being Too Cold
- Reduced Thermal Stress on Occupants From Being Too Hot
- Reduced Asthma-Related Healthcare and Costs
- Increased Productivity at Work Due to Improvements in Sleep
- Increased Productivity at Home Due to Improvements in Sleep
- Fewer Missed Days at Work
- Reduced Use of High Interest, Short-Term Loans
- Increased Ability to Afford Prescriptions
- Reduced Heat or Eat Choice Dilemma Faced by Pregnant Women
- Reduced Need for Food Assistance

These NEIs were chosen for monetization because the evaluation collected data pertinent to measuring the direct outcomes and/or monetizable outcomes related to each NEI. For example, the national Occupant Survey asked respondents pre- and post-weatherization and a comparison group post-weatherization about thermal stress, asthma symptoms and medical treatment, improvements in sleep, missed days at work, etc. The evaluation also collected information on measures installed by WAP in a representative sample of homes that was used to estimate reduced carbon monoxide poisonings and home fires.

It should be noted that, in general, homes do need to receive a full complement of major weatherization measures (e.g., air sealing, insulation, HVAC replacement/repair) to generate the types of NEIs described. Findings from the national WAP evaluation showed that enough homes received a sufficient level of measures to yield significant non-energy benefits. It should also be noted that while every household is expected to receive energy cost reduction benefits from weatherization, not every household is expected to receive the health and household-income related benefits identified through the national WAP evaluation. For example, only a subset of households will experience thermal stress events in the absence of home weatherization, so fewer households are available to receive this benefit than will experience energy cost reductions.

1.1.1 Discussion—Sample Sizes and Statistical Significance

There are a multitude of health studies conducted that consist of small sample sizes that represent respectable research. During the data analysis design phase, Three[3] did face the issue of whether sample sizes were large enough to capture rare events. For example, the Occupant Survey asked questions about fires and CO poisoning pre- and post-weatherization. The responses indicated that both were very rare given our sample size, and national data supports these conclusions. However, preventing fires and CO poisoning are policy relevant and important NEIs of weatherization. We therefore believe that estimating the monetized benefits of reducing fires and CO poisoning are worthwhile given that deaths could be prevented. So, in these two instances, data collected through the national evaluation on weatherization measures installed (e.g., various measures that map specifically to fire ignition risks or serve as fire suppressors), national Occupant Survey responses for CO monitors installed that may reduce the incidence of CO poisoning, along with secondary data were relied upon to anchor the methodologies.

In the case of thermal stress, had the sample size been larger (and possibly included large multifamily units) one could argue that findings would have been more statistically robust than they were. Again, the magnitude of the change in medical needs from pre- to post-weatherization is enough to be policy relevant.

Hospitalizations for asthma are also considered rare events within the general population, which is where the analysis began for the asthma sample; emergency department (ED) visits are less rare and were therefore observed more often than hospitalizations in the pre-weatherized treatment group. The improvement in asthma morbidity as measured by ED visits in the asthma sample was determined to be statistically significant. Although a reduction in hospitalizations for asthma was observed post-weatherization, it was not statistically different from zero. It is believed this is a result of a small sample size and a rare event.

Additionally, health and safety-related findings are augmented by anecdotal evidence offered by the human stories shared by the weatherization agencies and by recipients of the programs themselves. Ultimately, these benefits were analyzed from multiple angles. Triangulation as a research method (i.e., arriving at conclusions by using multiple sources of information) is common within the social sciences. Because the benefits selected for analysis were approached in this way, the Three[3] researchers were able to confidently monetize changes in occurrences even if they did not achieve statistical significance for the reasons explained above. A national panel of experts reviewed all methodologies and assumptions—the panel did not question the validity of any of the NEIs nor were the findings dismissed as inconsiderable as there was a clear indication of health improvements.

1.2 Presentation of Findings

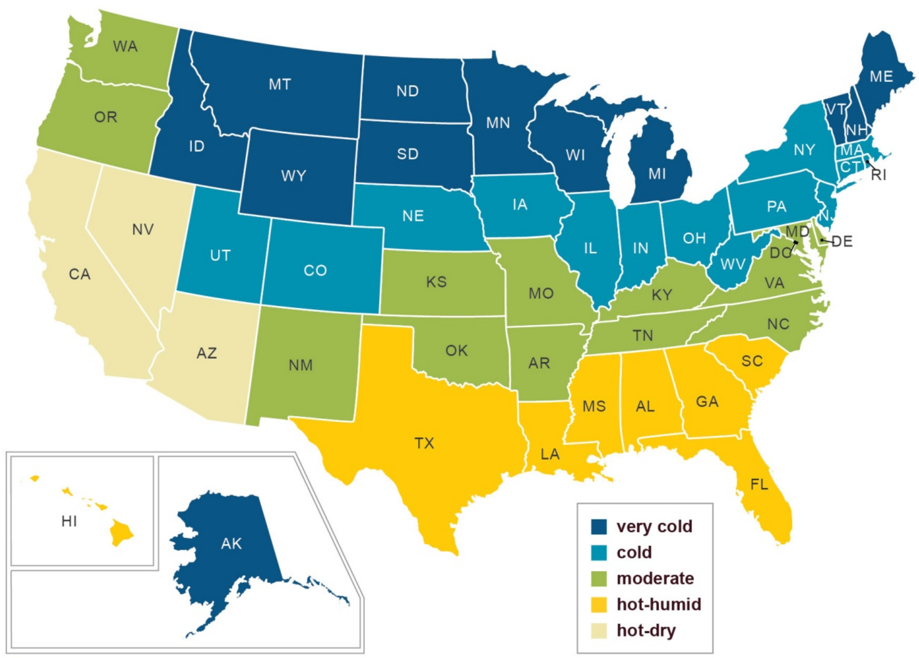
For the national WAP evaluation, the estimated NEI values were presented on a dollar per weatherized unit basis, broken down by both societal and household benefit components as well as including estimated values for both with and without the value of lives saved. The present value (PV) of the benefits was estimated over a ten-year time horizon[22], using the discount rate of 0.1% published by the Office of Management and Budget for Fiscal Year (FY) 2013. The estimates were presented in three tiers. Tier 1 estimates were based on observed monetizable outcomes attributable to weatherization (i.e., observed through the national Occupant Survey, pre- and post- weatherization with a comparison group) and highly reliable cost data. Tier 2 and 3 estimates were established to have underlying sound methodologies, but may have lacked direct observations of improved health or well-being (e.g., based on counts of installed CO monitors rather than on survey reports of fewer CO poisonings post-weatherization) and/or required relatively more assumptions.

[22] With the exception of the non-energy benefit of installing CO monitors, where present value was calculated over a more conservative 5-year period as the lifespan of CO monitors generally remains effective for an average of five years.

2.0 Massachusetts Low-Income Health- and Safety-Related Non-Energy Impacts

Data for households located in the cold region of the U.S. (comparable to the MA climate) (Figure 2.1) were mined from survey findings from the national Occupant Survey administered to recipients of DOE's WAP, as well as to a comparison group. Data for households located in the very cold region of the U.S. were also considered for inclusion. Combining the cold and very cold climate regions to increase statistical significance was explored. The inclusion of the very cold climate zone into the sample versus the utilization of regional or national data for the cohort sample for select NEIs, was discussed with the project team.

Figure 2.1. Climate Regions



The project team decided consistency with respect to climate region for the cohort sample was preferred. For most of the NEIs, the size of the cold climate region sample was more than sufficient, and combining cold and very cold climate regions did not increase the statistical significance by much, if any. Furthermore, in a few instances, the results between the two climate zones were too different to be able to defend their combination. Table 2.1 provides the recommendations and reasoning for cohort sample selection.

Table 2.1. Recommendations and Reasoning for Cohort Sample Selection

NEI	Recommendation for Cohort Sample Selection	Reasoning
Asthma Symptoms	**National**	Asthma prevalence does not vary significantly by climate region. In order to capture the potential impacts, a more robust sample size would be beneficial.
Medical Attention – too cold	**Cold Climate Region**	Impacts are directly related to climate region.
Medical Attention – too hot	**Cold Climate Region**	Impacts are directly related to climate region.
Missed Days of Work (avg. # days)	**Cold Climate Region**	Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values.
Use of Short Term Loan	**Cold Climate Region**	Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values.
Respondents That Did Not Get Enough Rest or Sleep Previous Month	**Cold Climate Region**	Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values.
Have Working CO Monitor	**Cold Climate Region**	Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values.
Have Smoke Detector	**Cold Climate Region**	Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values.

2.1 Descriptive Statistics

The tables below present data for the pre- and post-weatherization treatment groups and the post-weatherization comparison group. For all NEIs, with the exception of asthma, data is presented for the cold climate region only—for the asthma NEI, national level data is presented. Cohort sample sizes by the cold climate region for seven of the eight NEIs are included in Table 2.2, with asthma sample sizes in Table 2.3. Table 2.4 characterizes the cohort sample with respect to housing and demographics, and Table 2.5 and 2.6 present frequencies from the Occupant Survey for health and household related variables. Tables 2.7-2.12 present the reported decrease in occurrence (in %), and the statistical significance of these values, for thermal stress, poor rest/sleep, use of short-term loans, missed days of work, home fires, and CO poisoning. Table 2.13 presents this same data for the national asthma sample cohort.

Table 2.2. Cohort Sample Sizes for Cold Climate Region

	Sampled Groups		
	Pre-Wx Treatment (Survey Phase 1)	Post-Wx Treatment (Survey Phase 2)	Post-Wx Comparison (Survey Phase 1)
Cold Climate Region	318	190	331

Table 2.3. Sample Sizes for Respondents That "Have Been Told They Have Asthma" and Those That "Still Have Asthma"

	Sampled Groups		
	Pre-Wx Treatment (Survey Phase 1)	**Post-Wx Treatment (Survey Phase 2)**	**Post-Wx Comparison (Survey Phase 1)**
National – All	94	61	123

Table 2.4. Housing and Demographic Characteristics

	Sampled Groups	
	Pre-Wx Treatment (Survey Phase 1)	**Post Wx Comparison (Survey Phase 1)**
% Single-Family Homes*	75%	80%
Heating Fuel - Natural Gas**	61%	57%
Heating Fuel - Electric	11%	10%
Heating Fuel – Fuel Oil	12%	22%
Heating Fuel – Propane	7%	6%
Heating Fuel – Kerosene	7%	5%
Heating Fuel – Wood	3%	0.3%
Age Respondent (in yrs.)	56	68
Household Size	2.6	2.2
Respondent Employed	33%	34%
Home in Rural Area	29%	29%
Respondent Married	34%	34%
Respondent Education – High School	41%	42%

*Mobile homes and small multi-family (2-4 units) constituted the remaining percent.
**Percentages of heating fuel types might not total 100% due to rounding.

Statistical tests were conducted to assess the differences between the pre-weatherization treatment and post-weatherization treatment and comparison groups. Asterisks found in the second and third columns of Table 2.5 and Table 2.6 indicate whether a statistically significant difference exists between the pre-weatherization treatment and post-weatherization treatment groups and the pre-weatherization treatment and post-weatherization comparison groups, respectively.

Table 2.5. Health and Household Variables Related to Select NEIs (Cold Climate Region)

	Sampled Groups		
	Pre-Wx Treatment (Survey Phase 1)	**Post-Wx Treatment (Survey Phase 2)**	**Post-Wx Comparison (Survey Phase 1)**
Medical Attention – too cold	4.1%	2.6%	1.8%
Medical Attention – too hot	3.8%	1.1%	0.9%*
Missed Days of Work (ave. # days)	10.6	4.1	9.1**
Used Short Term Loan	18%	9%	13%**
Respondents That Did Not Get Enough Rest or Sleep Previous Month	68%	66%	60%*
Have working CO Monitor	54%	81%***	90%***
Have Smoke Detector	94%	97%	98%***

*** p<.001, ** p<.01 and *p<.05

Table 2.6. Health Variables Related to Asthma (National Sample)

	Sampled Groups	
	Pre-Wx Treatment (Survey Phase 1)	**Post-Wx Treatment (Survey Phase 2)**
Asthma Emergency Department	15.8%	4.3%*
Asthma Hospitalization	13.7%	10.6%
Asthma Symptoms < 3 months ago (i.e. high-cost patient)	70.5%	58.7%

*** p<.001, ** p<.01 and *p<.05

2.2 Monetization Approach

For six of the eight NEIs addressed by this research, the results of the national Occupant Survey were used as the basis for the monetization approaches as sample size was sufficient to indicate observable impacts from pre- to post-weatherization. For two of the NEIs, carbon monoxide (CO) poisoning and fire prevention, the data sources were different. The Occupant Survey did include questions specific to instances of CO poisoning and home fires; however, these events are relatively infrequent. Instead, data was collected from local weatherization agencies on the number of CO monitors installed that could reduce the probability of CO poisoning, and the number of smoke detectors installed, as well as other weatherization measures that could reduce the probability of home fires.

The tables for CO monitors and smoke detectors contained in this piece are based on data related to the number of installations of these measures, as subjectively reported by the respondents (weatherization agencies). The data, which were collected pre- and post-weatherization, indicated generally statistically significant changes from pre- and post-weatherization for these measures. The data from the local weatherization agencies were used instead of the Occupant Survey data because the former were judged to be more statistically robust, with a much higher sample size.

The decrease in occurrence for all NEIs, with the exception of asthma, between pre- and post-treatment groups and between pre- treatment and post-comparison groups was calculated (i.e., an average of the differences) (see Equation 1). This approach was utilized to make the best use of the collected data. The equation utilized for asthma will be presented in the next section.

Equation 1. [(Pre-Wx Treatment – Post-Wx Treatment) + (Pre-Wx Treatment – Post-Wx Comparison)] / 2

In Tables 2.7 – Table 2.12, column 1 presents the Pre-Wx Treatment – Post-Wx Treatment values (decreased occurrence), column 2 presents the Pre-Wx Treatment – Post-Wx Comparison values (decreased occurrence), and column 3 presents the value resulting from the application of Equation 1, equaling the total decrease in occurrence. Statistical significance (p-value) was explored, utilizing the appropriate statistical analyses, and is presented within the tables as well.

Table 2.7. Thermal Stress

	Decrease in Occurrence: Difference between Pre-Wx (N=318) and Post-Wx Treatment (N=190)	Decrease in Occurrence: Difference between Pre-Wx Treatment (N=318) and Post-Wx Comparison (N=331)	Total Decrease in Occurrence
Medical Attention – too COLD	1.5%	2.3%	1.9%
Exact Sig. (2-tailed)*	.754[a]	.104[b]	
Medical Attention – too HOT	2.7%	2.9%	2.8%
Exact Sig. (2-tailed)*	.125[a]	.018[b]	

*Statistically significant if p<.05; [a.]McNemar Test; [b.]Fisher's Exact Test

Table 2.8. Missed Days of Work

	Decrease in Occurrence: Difference between Pre-Wx (N= 92) and Post-Wx Treatment (N= 60)	Decrease in Occurrence: Difference between Pre-Wx Treatment (N= 92) and Post-Wx Comparison (N=89)	Total Decrease in Occurrence
Reduction in Missed Days of Work Past Year (Days)	6.5	1.5	4.0
Paired Samples (2-tailed)	.891	-	-
One-way ANOVA	-	.013	-

*** p<.001; ** p <.01; * p<.05

Table 2.9. Use of Short-Term Loans

	Decrease in Occurrence: Difference between Pre-Wx (N=314) and Post-Wx Treatment (N= 186)	Decrease in Occurrence: Difference between Pre-Wx Treatment (N= 314) and Post-Wx Comparison (N=327)	Total Decrease in Occurrence
% Reduction in Reporting Used at Least One Short-Term Loan in Previous Year	8.3%	4.6%	6.45%
Exact Sig. (2-tailed)*	.55[a]	.002[b]	-

*Statistically significant if $p<.05$; [a.]McNemar Test; [b.]Fisher's Exact Test

Table 2.10. Poor Sleep/Rest

	Decrease in Occurrence: Difference between Pre-Wx (N= 315) and Post-Wx Treatment (N=181)	Decrease in Occurrence: Difference between Pre-Wx Treatment (N= 315) and Post-Wx Comparison (N= 326)	Total Decrease in Occurrence
% Reduction in Reports of # of Days in Previous Month Slept/Rested Poorly	2.0%	8.0%	5.0%
Exact Sig. (2-tailed)*	.511[a]	.04[b]	-

*Statistically significant if $p<.05$; [a.]McNemar Test; [b.]Fisher's Exact Test

Table 2.11. Have CO Monitor

	Decrease in Occurrence: Difference between Pre-Wx (N= 312) and Post-Wx Treatment (N=190)	Decrease in Occurrence: Difference between Pre-Wx Treatment (N=312) and Post-Wx Comparison (N=327)	Total Decrease in Occurrence
% Increase in Having a CO Monitor	27%	36%	29%
Exact Sig. (2-tailed)*	.000[a]	.000[b]	-

*Statistically significant if $p<.05$; [a.]McNemar Test; [b.]Fisher's Exact Test

Table 2.12. Have Smoke Detector

	Decrease in Occurrence: Difference between Pre-Wx (N=317) and Post-Wx Treatment (N=189)	Decrease in Occurrence: Difference between Pre-Wx Treatment (N= 317) and Post-Wx Comparison (N= 330)	Total Decrease in Occurrence
% Increase Having a Smoke Detector	3%	4%	3.5%
Exact Sig. (2-tailed)*	.180[a]	.112[b]	-

*Statistically significant if $p<.05$; [a] McNemar Test; [b] Fisher's Exact Test

As mentioned previously, the equation (Equation 2) utilized for the monetization approach for the asthma NEI was different from the other seven NEIs due to the diverging sample characteristics between the treatment and comparison groups (see Section 3.1) and is as follows:

Equation 2. Pre-Wx Treatment – Post-Wx Treatment

Table 2.13 presents the reported decrease in occurrence (in %), and the statistical significance of these values from similar statistical analyses utilized previously, as well as from a logistic regression model.

Table 2.13. Asthma

	ED Visit from Asthma (Decrease in Occurrence)	Hospitalization from Asthma (Decrease in Occurrence)	High Cost Asthma Patient (Decrease in Occurrence)
Difference between Pre-Wx and Post-Wx Treatment (%)	11.5%	3.1%	11.8%
N[23]	47	47	46
Fisher's Exact Test (p-value)	.445	.154	.002
McNemar Test	1.000	.727	.388
Logistic Regression (n=130)	.035*	NA	NA

*The results from the logistic regression analysis indicate that weatherization is associated with fewer visits to the ED for asthma.

2.3 Modifications to Monetization Methods

A variety of modifications were made to the methodology and to the values of inputs utilized for the national NEI monetization models. In order to conduct a state-level analysis, inputs need to reflect the context. Each NEI section includes a listing of adjustments made, followed by the adjusted value of the input. Modifications that were applied to all NEIs are as follows:

[23] The number of respondents who answered the survey questions referred to in Table 2.13 was less than the number of respondents who answered the questions referred to in Table 2.3.

- Only per unit/household impacts were monetized, and any values related to program-wide impacts included in the equations utilized for the national WAP evaluation were removed (i.e., number of homes treated by WAP in PY 2008).
- The discount rate was adjusted from a very low Office of Management and Budget (OMB) rate of 0.1% to a twenty-year discount rate of 0.44%.[24,25]
- The Value of Statistical Life (VSL) was updated from $7.5M[26] to the U.S. Department of Transportation's (DOT) recommended value for 2016 of $9.6M (See Section 2.3.1).
- Lastly, per recommendations of the MA NEI study project team, the VSL associated with avoided deaths was applied as a household benefit rather than a societal benefit.[27]

2.3.1 Avoided Death Benefits

To monetize the benefit of avoided deaths from thermal stress, CO poisoning, and fire, the VSL was adjusted and updated from the $7.5M (2008 dollars) used in the national WAP evaluation to $9.6M (2015 dollars), as published in the DOT forthcoming guidance document for 2016.[28] The DOT issues annual updates to the VSL to adjust for changes in prices and real incomes. Federal agencies including DOT and U.S. Environmental Protection Agency (EPA) use the VSL to assess the benefits of their regulations or policies intended to reduce deaths or fatalities (e.g., from traffic accidents or adverse environmental events/conditions). The last known VSL published by the EPA is $7.4M (2006 dollars), which is to be updated to the year of analysis.[29] An article published in *Risk Analysis* provides an overview of VSL application in federal regulatory analyses and states: 1) EPA's and DOT's estimates have become remarkably similar; both now use central VSL estimates somewhat above $9 million; 2) this increasing similarity appears to result at least

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[24] The national WAP evaluation used the ten-year real treasury interest rate for 2013 (0.1%) from Office of Management and Budget (OMB) to calculate the present value (PV) of the total discounted savings for all NEIs.

[25] The use of a 0.44% discount rate over a period of twenty years to calculate the PV is consistent with the discount rate and the measure life for low-income weatherization used in the MA PAs' Three-Year 2016-18 Plan.

[26] Value of human life, or as economists refer to it as, the Value of Statistical Life (VSL) is a measure used to compare regulatory costs to benefits. At the time of the WAP evaluations, the U.S. government agencies were using values ranging from $5-9 million in regulatory cost-benefit analysis. The WAP National Evaluation used a conservative VSL of $6 million (2000 dollars) adjusted for inflation to $7.5 million in 2008 dollars. See OMB Circular A-4 for more discussion on VSL.

[27] EPA does not explicitly state that the effect of the VSL costs and benefits should be applied as societal or household impacts; this lack of guidance has resulted in conflicting schools of thought on this matter. Based on consultation with health economists, the WAP National Evaluation chose to apply avoided costs as a societal benefit. However, based on additional research, it is clear that VSL estimates are based on the value that individuals' place on reducing their own mortality risk. Thus, for this study, it was decided to categorize VSL as a household benefit (See Section 2.3.1 for more detailed information on this decision).

[28] DOT's annual VSL guidance for 2016 is forthcoming (Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analysis). In the interim, the updated VSL is published in DOT's Benefit-Cost Analysis (BCA) Resource Guide, updated March 1, 2016, available at https://www.transportation.gov/sites/dot.gov/files/docs/BCA%20Resource%20Guide%202016.pdf. DOT's 2015 guidance document, dated June 17, 2015, is available at https://www.transportation.gov/sites/dot.gov/files/docs/VSL2015_0.pdf.

[29] EPA. Mortality Risk Valuation. Available at https://www.epa.gov/environmental-economics/mortality-risk-valuation#whatisvsl.

in part from reliance on the same type of research (wage risk studies); and 3) DOT has updated its guidance more frequently than EPA (Robinson and Hammitt 2015).[30]

It is also important to note that the VSL does not refer to the "value of a life" but rather as the value of a change in one's mortality risk. From the DOT guidance, the VSL is "defined as the additional cost that individuals would be willing to bear for improvements in safety (reductions in risks) that, in the aggregate, reduce the expected number of fatalities by one...what is involved is not the valuation of life as such, but valuation of reductions in risk."

Discussion arose regarding whether a VSL more specific to the low-income population has been developed and can therefore be applied in this study. Age-specific VSLs, which have been studied, can be related, in part, to income level. However, the literature shows "that the relationship between age and WTP (willingness to pay) for mortality risk changes is ambiguous" and the empirical evidence and state preference results are mixed (EPA 2010).[31] Furthermore, for policy reasons and because DOT regulations typically affect a broad cross-section of people, DOT guidance explicitly assigns a single, nationwide VSL regardless of age, income, or other distinct characteristics of the affected population, the mode of travel, or the nature of the risk." EPA similarly applies a single VSL value and had discontinued its use of age adjustments (lower VSL for older age groups) after its "review of emerging research suggested that the effects of age on VSL were highly uncertain" (Robinson & Hammitt 2015).[32] Regardless if VSLs had been developed specific to age-groups or income-level, the study team decided that any such adjustment would reflect a devaluation of life in both circumstances and therefore seemed unethical.

Finally, the benefit of avoided deaths (except for firefighters) is being applied in this MA-specific study as a household benefit. Cost benefit analyses conducted at the federal level do not typically distinguish benefits accrued to individuals/households apart from society as a whole. In accordance with MA state guidelines for assessing the cost effectiveness of the PAs' energy efficiency programs, the avoided death benefits assessed in this study are consistent with the allowable class of benefits that accrue to program participants/households.[33] For example, the PAs currently apply a benefit for avoided fire and carbon monoxide deaths attributable to its low-income program for heating system replacement and repair, as estimated in the 2011 NMR NEI study, as a benefit to program participants. Conversely, the avoided death benefits estimated herein do not appear to be in the same class as the "societal" NEIs that had been assessed and quantified in the 2011 NMR study, but subsequently disallowed for use by the State because they do not accrue to program participants. These disallowed "societal" NEIs include those associated with the benefits of reducing the need for foreign energy imports; avoiding landfill space and recycling; and increasing jobs, business sales, and gross state product.[34]

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[30] Robinson, Lisa A. and Hammitt, James K. "Research Synthesis and the Value per Statistical Life," *Risk Analysis*, Vol. 35, No. 6, 2015, p. 1088.
[31] USEPA. Appendix B: Mortality Risk Valuation Estimates, *Guidelines for Preparing Economic Analysis*, December 2010, p. B-5., available at https://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf.
[32] Robinson, Lisa A. and Hammitt, James K. "Research Synthesis and the Value per Statistical Life," *Risk Analysis*, Vol. 35, No. 6, 2015, p. 1090.
[33] Massachusetts Department of Public Utilities, Section 3.4.4.1, "Energy Efficiency Program Cost-Effectiveness," from Guidelines for the Methods and Procedures for the Evaluation and Approval of Energy Efficiency Plans and Energy Efficiency Reports, revised January 31, 2013.
[34] Massachusetts Department of Public Utilities, D.P.U. 12-100 through D.P.U. 12-111, Order of Three-Year Energy Efficiency Plan for 2013 through 2015, January 31, 2013, pp. 105-106.

The project team also explored whether a different VSL value is being used by regulatory agencies in MA (e.g., MA Department of Transportation (MADOT), MA Department of Environmental Protection (MADEP)), but did not find any in the published literature or through inquiries made to agency personnel. However, the project team did find a 2010 MADOT publication that references the USDOT's 2009 VSL to monetize the value of accidental traffic deaths that can be prevented through improvements to freight infrastructure and operations in the Commonwealth.[35]

2.4 Presentation of Findings

The presentation of estimated NEI values for the MA LI SF NEI study are similar to the national WAP evaluation in that values are presented on a per weatherized unit basis, broken down by their societal and household benefit components, a PV estimate of the benefits is provided, and estimates are presented in three tiers. The main contributors to these estimates are: avoided deaths from CO poisoning, fire, and thermal stress; avoided hospitalizations and ED visits related to these three areas as well as asthma-related symptoms; and disposable income gains from fewer missed days at work.

[35] Massachusetts Department of Transportation, Chapter 4, Freight Investment Scenarios, Freight Plan, September 2010, pp. 4-10 through 4-11.

3.0 Reduced Asthma

Weatherization has the potential to act as a multi-component intervention mitigating the severity and incidence of asthma episodes by addressing multiple triggers in the home environment. Weatherization reduces the number and potency of home-based environmental asthma triggers, resulting in fewer asthma symptoms, direct medical costs, and indirect costs. This analysis explores the transferability of the monetized benefits of weatherization delivered through WAP to the Massachusetts PAs' weatherization programs relevant to this study.

Weatherization measures address multiple evidence-based indoor environmental triggers (e.g., mold, cockroaches, mice, dust, other particulate matter, and by-products of combustion from gas cooking stoves and portable unvented heaters) covered by public health campaigns and community health education programs tasked with reducing asthma morbidity.

3.1 National WAP Evaluation—Summary of NEI Analysis

Tables 3.1 and 3.2 characterize the national WAP population with regards to asthma prevalence. Respondents were initially asked if they had "*ever* been told by a physician" that they have asthma. If the respondent answered in the affirmative, they were then asked if they *still* have asthma. The results from the survey indicate that 16.8% of adults in the WAP eligible population have asthma. Descriptive frequencies were generated for all respondents who reported still having asthma in either phase of the survey, and for those who responded to both pre- and post-weatherization surveys.

Due to the diverging sample characteristics between treatment and comparison groups, changes in responses pertaining to asthma control and associated urgent care utilization were monetized using the treatment group responses only pre- and post-weatherization. The national Occupant Survey posed these two questions to the respondent reporting current asthma diagnosis:

During the past 12 months did you have to stay overnight in the hospital because of asthma?__________________

Not counting hospitalizations, during the past 12 months, did you go to an emergency room because of asthma?__________________

Tables 3.1 and 3.2 present the final descriptive frequencies for the monetization of these benefits attributed to weatherization.

Table 3.1. Reduction in Asthma Related ED Visits for All Respondents Reporting Current Diagnosis of Asthma

% of Respondents Reporting Visit to ED due to asthma[36]	ED Visit	Difference
Whole Asthma Sample-Treatment Group (Pre-Wx; n=95)	15.8%	(-) 11.5%*
Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=47)	4.3%	

*** p<.001; ** p <.01; * p<.05

[36] The number of respondents who answered this survey question is one more than the number in Table 2.3, One additional survey respondent answered this question, but was not on record for answering the survey questions in Table 2.3.

Table 3.2. Reduction in Asthma Related Hospitalizations for All Respondents Reporting Current Diagnosis of Asthma

% of Respondents Reporting Hospitalization due to asthma[37]	Hospitalization	Difference
Whole Asthma Sample-Treatment Group (Pre-Wx; n=95)	13.7%	(-) 3.1%
Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=47)	10.6%	

*** p<.001; ** p <.01; * p<.05

The non-energy benefit attributable to fewer ED visits was monetized as follows:

*Benefit = (number of persons served by WAP in PY 2008) * (asthma prevalence for adults and children)[38] * (reduction in ED visits) * (frequency of re-admittance (adults and children)) * (average hospital costs (adults and children))*

The non-energy benefit attributable to fewer hospitalizations was monetized as follows:

*Benefit = (number of persons served by WAP in PY 2008) * (asthma prevalence for adults and children) * (reduction in hospitalizations) * (frequency of re-admittance (adults and children)) * (average hospital costs (adults and children))*

As stated, in addition to averted medical costs associated with hospitalization and ED visits due to asthma, there is sufficient evidence to suggest that weatherization acts in part as a home-based multi-trigger or multi-attribute asthma reduction program providing additional benefits beyond the changes in utilization of urgent care captured in the survey. These benefits are observed through other direct medical costs (i.e., reduced prescribed medicines, office and clinic visits, and hospital outpatient) and indirect costs (i.e., reduced housekeeping loss, loss of work and school productivity, and restricted activity).

In efforts to monetize potential reductions in averted medical costs and indirect costs outside of urgent care treatment provided through ED visits and hospitalizations, a methodology was developed to identify individuals as "high-cost" asthma patients pre-weatherization, but then identified as "low-cost" asthma patients post-weatherization. Based on respondents' reports of the last time they had asthma symptoms, compared to those who reported ED visits or hospitalizations due to asthma, a framework was developed to identify respondents as either high or low-cost asthma patients. Those who reported last having asthma symptoms less than three months ago were counted as high-cost asthma patients and those who reported last having asthma symptoms greater than three months ago were identified as low-cost asthma patients. Table 3.3 provides the reduction in high-cost patients in the treatment group whole asthma sample (11.8%). This reduction in percentage was used for the monetization of the benefit.

[37] The number of respondents who answered this survey question is one more than the number in Table 2.3, One additional survey respondent answered this question, but was not on record for answering the survey questions in Table 2.3.

[38] Adult prevalence used for the WAP eligible population was estimated using self-reported survey data (16.8%). Child prevalence was estimated based on national statistics—10.1% for poor white children and 16.0% for poor non-hispanic black children. The portion of WAP population receiving services was estimated using demographic data from the occupant survey: 19% non-hispanic black and 81% other. The benefit is computed and monetized assuming both adults and children (not just the adult head of household) are affected by asthma in a given household based on their respective prevalence rate and medical costs.

Table 3.3. Reduction in High-Cost Patients

% of Respondents Identified as High-Cost Asthma Patient by Group and by Sample[39]	High-Cost	Difference
Whole Asthma Sample-Treatment Group (Pre-Wx; n=93)	70.5%	(-) 11.8%
Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=46)	58.7%	

*** p<.001; ** p <.01; * p<.05

The non-energy benefit from a reduction in direct medical costs outside of ED visits and hospitalization, and from a reduction in indirect costs associated with high-cost asthma patients within the whole asthma sample treatment group was monetized as follows:

*Benefit = (number of persons served by WAP in PY 2008) * (asthma prevalence for adults and children) * (reduction in high-cost patients) * (difference in high and low cost patients after extracting the ED visit and hospitalization costs already claimed))*

3.2 MA LI SF NEI Study

Changes in asthma-associated healthcare utilization and improved control were drawn from the entire national subsample of survey respondents reporting current asthma diagnosis and not for the cold and/or very cold regions only. Although indoor environmental asthma triggers are often specific to geographic and climate regions, and diverse across housing types, differences in overall prevalence within the general population by region are negligible. It was also determined that the estimated higher percentage of those with asthma found in the WAP eligible population will be used for estimating the monetized value of the NEI for this study instead of using Massachusetts state-level asthma prevalence for its general population. We apply the higher WAP-based asthma prevalence rate because previous findings suggest that households applying for services are motivated by energy affordability issues, as well as dwelling quality issues relatable to poor health status.

Final consideration was given to the use of national WAP evaluation outcomes related to changes from high to low-cost asthma patients post-weatherization and whether or not this issue had relevance in Massachusetts. According to the "2014 Costs Trends Report"[40] produced by the Health Policy Commission (HPC) in Massachusetts, asthma is indeed considered a key clinical condition for persistently high-cost patients.

For the above-mentioned reasons, methodologies (Section 3.1) for calculating the asthma-related benefits for WAP were employed for this study with the exception of the inclusion of reductions in indirect costs. Indirect costs were not used as inputs for this model due to the risk of double counting savings generated from other NEIs in this study (i.e. fewer missed days of work, increased productivity at home due to increased sleep).

[39] The number of respondents included in this analysis is fewer than the number referred to in Tables 2.3, 3.1 and 3.2 due to criteria filters used for high-cost patient analysis (i.e. still have asthma, answered survey questions related to asthma symtoms).
[40] Health Policy Commission. 2014 Cost Trends Report. Boston, MA 2014; http://www.mass.gov/anf/budget-taxes-and-procurement/oversight-agencies/health-policy-commission/2014-cost-trends-report.pdf

The new equation for calculating the direct medical savings (other than from reduced ED and hospitalizations) of the total asthma benefit is as follows:

*Benefit = (number of persons served by WAP in PY 2008) * (asthma prevalence for adults and children[41] * (reduction in high-cost patients) * (difference in high and low cost patients after extracting the ED visit, hospitalization, and indirect costs already claimed))*

Average state-level costs for asthma-related hospitalizations and ED visits were identified for FY 2009-2013 and used as inputs for the model.[42] To estimate impacts from changes in other direct medical costs, the WAP 2008 estimate was adjusted to 2014 costs. The out-of-pocket (OOP) costs were estimated to determine the household benefit, with the remaining medical costs incurred by private insurers, Medicaid, and Medicare considered as societal benefits. The HPC report (2014) suggests that, on average, commercially insured individuals with chronic health conditions spend approximately seven percent OOP of the total allowable healthcare costs incurred for that illness. This percentage was input as the household portion of the total asthma benefit calculated for the percentage of the population with commercial insurance and those uninsured (~ 43%).

3.3 Findings

Table 3.4 below presents the estimates of this NEI for the MA LI SF NEI study. This table includes the combined annual impacts per weatherized unit and PV of the impacts per unit, assuming a twenty-year life span of the weatherization measures, for reductions in ED visits, hospitalizations, and other direct healthcare costs.

Table 3.4. Estimated Impacts of Reduced Asthma-related Costs[43]

	Annual Per Unit Benefit	PV Per Unit Benefit
Households	$9.99	$190.92
Society	$322.01	$6,151.96
Total	**$332.00**	**$6,342.88**

Inputs

- National WAP evaluation findings on changes in asthma-related health status and healthcare utilization were used;
- Average cost for asthma-related hospitalization per adult for 2009-2013 was $8,381 resulting in an estimated savings of $82 per weatherized household;

[41] Adult and child prevalence used for the WAP eligible population was used for the MA LI NEI Study and was similarly computed and monetized assuming both adults and children (not just the adult head of household) are affected by asthma in a given household based on their respective prevalence rate and medical costs.
[42] Discharge data containing asthma costs for inpatient and ED admissions (without complication or comorbidity (CC)) for all age categories and payer types were retrieved from the Center for Health Information and Analysis (CHIA); http://www.chiamass.gov/utilization-analysis/. CHIA is an agency of the Commonwealth of Massachusetts.
[43] For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs was categorized as a societal benefit. For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (7% as copayments or deductibles) were categorized as a household benefit. For individuals/occupants that are "uninsured," the OOP costs (7% of total medical costs) were categorized as a household benefit.

- Average cost for asthma-realted hospitalization per child (0-17 years old) for 2009-2013 was $7,569 resulting in an estimated savings of $31 per household;
- Average related ED visits for all individuals for 2009-2013 was $1,503 resulting in an estimated savings of $82 per household;
- After inflation, the average cost of all "other" medical costs was estimated to be $3,221 for 2014 resulting in an estimated cost savings of $137 per household;
- Combined, the total per household asthma-related cost saving was estimated to be $332;
- The household benefit portion of the total estimated savings was calculated by applying the estimate that 43% of the low-income population in MA have commercial (private) insurance (37%) or are uninsured (6%) and by then applying the estimate that of those meeting this criteria, 7% of medical costs associated with a chronic illness are spent OOP for a total of $9.99 per household served benefit;
- The remaining estimated cost savings were attributed as a societal benefit totaling $332.01 per household served; and
- PV was estimated using the OMB .44% discount rate over a 20-year measure lifetime.

Finally, our analysis indicates that 9.9 asthma-related adult hospitalizations, 4.2 asthma-related child hospitalizations and 54.6 ED visits are prevented annually per 1000 units weatherized.

It is logical to claim that weatherization can reduce environmental asthma triggers in the home and thereby reduce the use of urgent care facilities, and other direct medical expenses and indirect expenses associated with asthma. It was observed through the national Occupant Survey that reported incidences of seeking urgent healthcare through the ED and hospitals from asthma were reduced post-weatherization.

The following conservative considerations and approaches were taken in devising the valuation of the asthma NEI for this study:

- The survey question asked if head of household had asthma and did not ask if any other adult or child in the household had asthma. Asthma prevalence was estimated based on the head of household response only, which may be an underestimate of the percent of adults and children with asthma in WAP eligible homes. If the percentage is indeed higher, then additional savings would accrue.
- State-level asthma prevalence for the general population in Massachusetts is higher than the national rate (11.4% compared to 7.3%[44]) and therefore may have a higher percentage of household members reporting asthma than the estimate used for this analysis: 16.8% across WAP homes nationally.
- The survey question asked those who responded in the affirmative of still having asthma if they have ever been to the ED or been hospitalized for asthma in the past 12 months, but did not ask the number of times. The cost savings estimate was calculated using only one urgent care event and readmittance rate for each affirmative response.
- According to national healthcare utilization sources used for monetizing this benefit, nearly 1/3 of those who visit the ED for asthma are readmitted within six months, with re-admittance to the hospital for adults (27.3%) and children (22.9%) also occurring. Frequency rates were only applied by calculating a savings benefit based on *one* re-admittance event despite the possibility that these events may have occurred multiple times.

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[44] Source: 2013 Behavioral Risk Factor Surveillance System (BRFSS) http://www.cdc.gov/asthma/brfss/2013/tableC1.htm

- The total benefit related to indirect costs (12%) was extracted from the cost savings attributed to better asthma control post-weatherization. This decision was made to eliminate the chance for "double-counting" of duplicate benefits accounted for elsewhere in the analysis (e.g., home productivity).
- The Black/African American population accounts for 19% of the WAP population served nationally. It is possible that in Massachusetts this minority and other communities of color make up a larger percentage of the population served through utility weatherization. Since communities of color tend to have higher asthma prevalence, poor asthma control, and more frequent use of urgent care, the cost savings from this benefit would be higher than the proposed estimates if higher rates are observed.
- OOP cost savings were applied to the percentage of the population in Massachusetts that are commercially insured or uninsured and does not consider OOP cost savings for Medicare or Medicaid recipients.

4.0 Reduced Thermal Stress on Occupants

Thermal stress caused by extreme indoor thermal conditions (i.e., temperature, humidity, drafts) can have significant adverse effects on health and mortality. According to the Mayo Clinic, the following people are most at risk for heat and cold-related illnesses:

- Elderly persons, pregnant women, and toddlers/infants
- Individuals with chronic medical conditions, mental disorders, or mobility impairments
- Any individual with inadequate food, clothing, or heating/cooling systems.

Low-income weatherization specifically targets this high-risk population. Weatherization decreases the chance of an individual being subjected to dangerously cold temperatures by addressing inadequate heating systems and insulation and decreasing excessive drafts in the home; alternatively, weatherization can address inadequate cooling systems and/or ventilation in the home to minimize heat-related illnesses.

4.1 National WAP Evaluation—Summary of NEI Analysis

The baseline and follow up national Occupant Survey posed the following two questions to each respondent:

*In the past 12 months, has anyone in the household needed medical attention because your home was too cold?*__________________

*In the past 12 months, has anyone in the household needed medical attention because your home was too hot?*__________________

Survey results revealed the number of times that occupants were required to seek medical attention due to exposure to extreme temperatures inside their home was reduced post-weatherization.[45] Taking an average of differences (see Equation 1) yielded a decreased rate of seeking medical attention for cold- and heat-related illnesses of 1.4% and 1.1%, respectively (see Tables 4.1 and 4.2). One could argue that regardless of the incremental drop in rates of occurrence within this particular sample, these results have major policy implications.

Equation 1. Change =
[(Pre-treatment – Post-treatment) + (Pre-treatment – Comparison group one year post-weatherization)] / 2

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[45] The project team considered to what extent the observed reductions in thermal stress could also be attributed to energy assistance subsidies funded Low-Income Home Energy Assistance Program (LIHEAP) (supported both by State level and the U.S. Department of Health and Human Services (DHHS) funds), especially first-time assistance. The incidence of thermal stress reported by households in the national occupant survey living in the cold climate zone was analyzed for households that did and did not report receiving LIHEAP. Nationally, about 50% of the survey respondents reported receiving LIHEAP assistance and 10% were first-year recipients at the time of the survey. The results suggest that households that reported receiving LIHEAP came into WAP somewhat "worse off" in that they originally suffered more incidences of thermal stress and also showed more improvement with respect to this metric post-weatherization. These results, however, do not support a strong conclusion about the extent to which this improvement is due to LIHEAP, their worse-off condition to begin with, and/or weatherization. Further, since not all weatherized homes receive LIHEAP, households typically receive energy assistance for multiple years, and LIHEAP payments are not timed to coincide with extreme weather events that are linked to thermal stress, we conclude that LIHEAP may potentially influence the observed reductions in thermal stress, but its contribution is uncertain and likely minimal.

The Occupant Survey did not provide a follow on question in order for the respondent to specify which *type* of medical attention (i.e., hospitalization, ED visit, physician office visit) was needed. Nor were questions asked regarding the death of a household member that may have occurred within the past 12 months due to thermal stress. Therefore, in order to accurately estimate total cost savings associated with the reduction of medical treatment and avoided deaths due to thermal stress, the following steps were taken:

- Secondary data sources were mined to establish the incidence rate, for the general U.S. population, of types of medical treatment used to treat these conditions.[46]
- A ratio based on the incidence of treatment type, from weighted averages over a 5 year period, was applied to the overall percent reduction in seeking medical treatment (Occupant Survey), for both cold and heat-related thermal stress.
- Average cost for each type of medical treatment were mined from the same secondary data source, and multiplied by the incidence of treatment type ratio.
- The percentage of death following hospitalization treatment for both cold and heat-related thermal stress, for general U.S. population, was mined from secondary data source.[47]
- Variables for “payer” (i.e., Medicare, Medicaid, Private/Other Insurance, Uninsured) were identified and isolated in order to group average yearly costs by payer. Average yearly out-of-pocket (OOP) costs were extracted from these costs.

The costs for treatment for cold and heat-related illnesses associated with thermal stress were retrieved from online databases provided by the Department of Health and Human Services (DHHS), sponsored by the Agency for Healthcare Research and Quality (AHRQ), based on the 2008 Medical Expenditure Panel Survey (MEPS)[48] as well as a collection of databases sponsored again by AHRQ referred to as the Healthcare Cost and Utilization Project (HCUP).[49]

Data related to incidence rates of treatment type and number of deaths following hospitalizations was mined from both MEPS and HCUP using the International Classification of Diseases diagnostic codes, associated with “Effects of reduced temperature” (ICD-9-CM 991.0-991.9) and “Effects of heat and light” (ICD-9-CM 992.0-992.9) as the queries. Several medical conditions are associated with exposure to extreme temperatures, with hypo- and hyperthermia being the most extreme, and less prevalent.

[46] It was assumed that the same national incidence rate for type of treatment could be applied to the WAP population. We believe this assumption results in a conservative estimate as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions. Therefore, one could argue the potential exists for the WAP population to require the higher-cost treatment (i.e., hospitalizations).
[47] Again, it was assumed, conservatively, that the same national rate of deaths following hospitalizations could be applied to the WAP population. We believe this is a conservative assumption as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions.
[48] Data generated from MEPS can be found on the following website: http://meps.ahrq.gov/mepsweb/
[49] These databases are derived from administrative data and contain encounter-level, clinical and nonclinical information including all-listed diagnoses and procedures, discharge status, patient demographics, and charges for all patients, regardless of payer (e.g., Medicare, Medicaid, private insurance, uninsured). HCUP is the largest collection of nationwide and state-specific longitudinal hospital care data in the United States and can be accessed at: http://www.ahrq.gov/research/index.html.

The inputs discussed above allowed for the annual cost savings of weatherization for the thermal stress NEI to be estimated. This total cost savings was further broken down and grouped as either a societal benefit or a household benefit.[50]

The NEI for reducing occurrences of medical treatment due to both cold and hot temperature exposure was monetized for the WAP evaluation using the following equations and inputs:

Variables

- Type of treatment:
    - *a = Hospitalization,*
    - *b = ED visit,*
    - *c = Physician office visit*
- *N (a, b, c)* = Total # of occurrences of medical treatment avoided, by treatment type
- Medical coverage type (i.e. payer):
    - p_1 = Medicare
    - p_2 = Medicaid
    - p_3 = Private/Other
    - p_4 = Uninsured (i.e., OOP)

Equations

Equation 2. *N (a, b, c) =*
[*(Number of WAP units completed in PY 2008) * (decreased rate of seeking medical care) * (% of type of medical treatment sought for cold and heat-related thermal stress (for a, b, and c)*]

Equation 3. *% of annual medical costs—(for p_1, p_2, p_3, p_4)—for WAP population (for a, b, and c) = [[(% of WAP population by medical coverage type) * (% of medical costs—by payer—for U.S. population (for a, b, and c)] / (% of U.S. population by medical coverage type)]]*

Equation 4. *Benefit (without avoided deaths) =*
*[(N (a, b, c) * % WAP medical costs (for p_1, p_2, p_3, p_4)) * Ave. cost for treatment (for a, b, and c)]*

Equation 5. *# of avoided deaths=*
*[(% of hospitalizations resulting in deaths (U.S. population) * (# of hospitalizations prevented by WAP in PY 2008)]*

Equation 6. *Total benefit (avoided deaths included) =*
*[# of avoided deaths * VSL]*

Inputs

- Reported decreased rate of seeking medical care (2008):
  Cold exposure, 1.4%; heat exposure, 1.1% (Occupant Survey)
- For treatment of cold-related illnesses (2008):
  Hospitalizations = 10.0%, ED visits = 39.9%, Physician office visits = 50.1%

[50] For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs was categorized as a societal benefit. For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (i.e., copayments and deductibles) were categorized as a household benefit. For individuals/occupants that are “uninsured,” all of the avoided medical costs was categorized as a household benefit.

- For treatment of heat-related illnesses (2008):
  Hospitalizations = 4.0%, ED visits = 84.5%, Physician office visits = 11.5%
- # of hospitalizations (general U.S. population, 2008): 3,410 (cold), 3,387 (hot)
- # of deaths following hospitalizations (general U.S. population, 2008): 122 (cold), 81 (hot)
- % of hospitalizations resulting in deaths (general U.S. population, 2008): 4% (cold), 2% (hot)
- # of hospitalizations prevented (WAP population, 2008): 113 (cold); 35 (hot)
- # of potential deaths avoided (WAP population, 2008): 4 (cold), 1 (hot)
- VSL - $7.5 M

4.2 MA LI SF NEI Study

Findings from the Occupant Survey specific to respondents residing in the cold climate zone of the U.S. (see Figure 2.1 in Section 2.0) were used to estimate the thermal stress NEI for this study. The descriptive statistics from this analysis are presented in Tables 4.1 and 4.2, along with national findings for comparison purposes.

Table 4.1. Reduction in Medical Care Needs due to Cold-Related Thermal Stress

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change
National	3.2%	1.5%	2.1%	1.4%
Cold Climate Zone	**4.1% (N=318)**	**2.6% (N=190)**	**1.8% (N=331)**	**1.9%**

*** p <.001, ** p<.01, *p < .05

Table 4.2. Reduction in Medical Care Needs due to Heat-Related Thermal Stress

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change
National	2.4%	1.5%	1.1%	1.1%
Cold Climate Zone	**3.8% (N=318)**	**1.1% (N=190)**	**0.9%* (N=331)**	**2.8%**

*** p <.001, ** p<.01, *p < .05

The following inputs and methodology used for the WAP evaluation were adjusted to produce an estimate of this benefit for the MA LI SF NEI study.[51]

- Rate of decreased medical care is based on findings from cold climate zone only: 1.9% (cold); 2.8% (hot) (see Table 4.1 and 4.2 above).
- National average medical costs from 2008 (used in WAP evaluation) were adjusted to reflect 2008 medical costs for the state of MA[52]; those costs were then price-inflated to reflect 2014 medical costs (see Tables 4.3 and 4.4).[53]
- Percent of medical costs paid, by payer, for each treatment type (a, b, and c)[54] (adjusted for WAP income-eligible population in 2008) was adjusted for the MA LI population[55] in 2014 (See Table A.1 and A.2 in Appendix A).

[51] See Table A.1 and A.2 in Appendix A for more detailed information related to inputs and calculations.
[52] More specifically, the Boston-Brockton-Nashua metropolitan statistical area (MSA).
[53] These adjustments were based using medical care price indices provided by the U.S. Bureau of Labor Statistics, http://data.bls.gov/timeseries/CUURA103SAM?data_tool=XGtable
[54] This cost and payer data was exported from MEPS and specific to ICD-9 primary diagnostic codes, "Effects of reduced temperature" (ICD-9-CM 991.0-991.9) and "Effects of heat and light" (ICD-9-CM 992.0-992.9). http://meps.ahrq.gov/mepsweb/

Table 4.3. Adjusted Medical Costs for Treatment of Cold-Related Thermal Stress

Average Costs: Cold-Related Thermal Stress		
Type of Treatment	**National 2008**	**MA 2014**
Hospital Visit	$9,455	$15,052
Household Cost	$776	$906
Societal Cost	$8,679	$14,146
ED Visit	$552	$980
Household Cost	$120	$350
Societal Cost	$432	$630
Physician Visit	$136	$248
Household Cost	$22	$32
Societal Cost	$114	$216

Table 4.4. Adjusted Medical Costs for Treatment of Heat-Related Thermal Stress

Average Cost: Heat-Related Thermal Stress		
Type of Treatment	**National 2008**	**MA 2014**
Hospital Visit	$5,802	$9,657
Household Cost	$451	$589
Societal Cost	$5,351	$9,068
ED Visit	$624	$980
Household Cost	$139	$350
Societal Cost	$485	$630
Physician Visit	$136	$248
Household Cost	$22	$32
Societal Cost	$114	$216

The following bullets document adjustments to inputs and refinements to methods related to estimating the benefits of avoided deaths from thermal stress for this study[56] (See Table 4.5):[57]

- % of hospitalizations resulting in deaths adjusted from national 2008 data to national 2013 data: 2.5% (cold); 1.28% (hot)[58]

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[55] http://kff.org/

[56] Due to insufficient data for 2014, all data related to deaths were from 2013. All national and state-level data related to hospitalizations and deaths following hospitalizations were mined from HCUP.

[57] See Table A.3 and A.4 in Appendix A for more detailed information related to inputs and calculations for avoided deaths from thermal stress.

[58] This data was unavailable at MA state level as sample sizes were too low to be reported; therefore, assumptions were made that the same national rate of hospitalizations resulting in death could be applied to the MA region.

- A rate of reduction in thermal stress deaths due to weatherization was calculated (See Table 4.5): 0.004776% (cold); 0.001434% (hot)

Equation 7.

*Rate of reduction in thermal stress reduction (%) = [(decreased rate of seeking medical care due to weatherization (cold climate zone)) * (% of hospitalizations sought for cold and heat-related thermal stress (national rate) * (% of hospitalizations from thermal stress resulting in deaths (national rate)]*

- VSL adjusted from $7.5 M to $9.6M and avoided deaths applied as a household benefit rather than a societal benefit

Table 4.5. Inputs—Estimating Avoided Deaths from Exposure to Extreme Thermal Conditions

	Cold-related	Heat-related
Rate of decreased medical care from thermal stress due to weatherization (based on occupant survey results for cold climate zone)	1.9%	2.8%
% of hospitalizations resulting in deaths from thermal stress (national rate, 2013)	2.5%	1.28%
Rate of reduction in deaths due thermal stress attributable to weatherization (based on occupant survey results for cold climate zone)	0. 004772%	.001434%
VSL	$9.6M	$9.6M
Household avoided death NEB$, per weatherized unit, per year	**$458.54**	**$137.65**

4.3 Findings

Tables 4.6 and 4.7 present estimates of the thermal stress NEIs specifically for low-income weatherization programs in MA state. These tables include both annual and PV benefits per weatherized unit, assuming persistence of measures for a twenty-year period. For cold-related medical conditions our analysis indicates that 0.05 deaths, 1.9 hospitalizations, 7.6 ED visits, and 9.5 physician office visits are prevented annually per 1000 units weatherized. For heat-related medical conditions our analysis also indicates that 0.01 deaths, 1.1 hospitalizations, 23.6 ED visits, and 3.2 physician office visits are prevented annually per 1000 units weatherized.

It should be noted that all thermal stress NEI values could be understated as it was assumed that extreme temperatures impact only one person per household (due to limitations of survey tool design) and results for any one year could be quite sensitive to extreme winter and summer weather events. Furthermore, estimates derived from existing data that include the general population is similarly conservative as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions.

Table 4.6. Estimated Impact of Reduced Medical Treatment and Avoided Deaths Due to Exposure to Extreme Cold Temperatures[59]

	Annual Per Unit Benefit	Annual Per Unit Benefit W/O Avoided Death Benefit	PV Per Unit Benefit	PV per Unit Benefit W/O Avoided Death Benefit
Households	$463.21	$4.67	$8,849.71	$89.30
Society	$33.73	$33.73	$644.47	$644.47
Total	**$496.94**	**$38.40**	**$9,494.18**	**$733.77**

Table 4.7. Estimated Impact of Reduced Medical Treatment and Avoided Deaths Due to Exposure to Extreme Hot Temperatures

	Annual Per Unit Benefit	Annual Per Unit Benefit W/O Avoided Death Benefit	PV Per Unit Benefit	PV per Unit Benefit W/O Avoided Death Benefit
Households	$145.93	$8.28	$2,787.95	$158.19
Society	$27.00	$27.00	$515.86	$515.86
Total	**$172.93**	**$35.28**	**$3,303.81**	**$674.05**

[59] For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs was categorized as a societal benefit. For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (i.e., copayments and deductibles) were categorized as a household benefit. For individuals/occupants that are “uninsured,” all of the avoided medical costs was categorized as a household benefit.

5.0 Fewer Missed Days of Work

Weatherization makes homes more comfortable, healthy, and safe. It is logical to presume that weatherization can lead to improvement in occupants' health. It is also logical to presume that improvements in occupants' health will allow employed occupants to miss fewer days of work due to illness or injury. Fewer missed days of work minimizes loss of pay, especially for employed respondents who do not have sick leave.[60] For those workers who do have sick leave, then a reduction of missed workdays would benefit their employers/society.

5.1 National WAP Evaluation—Summary of NEI Analysis

Numerous questions from the national Occupant Survey support the contention that occupants are healthier post-weatherization. Employed respondents[61] were directly asked how many days in the previous year they had missed work due to illness or injury of themselves and other family members both pre- and post-weatherization. Findings indicated fewer missed days of work (0.6 days) post-weatherization. Monetizing the estimated value of not missing a day of work was straightforward using published average hourly income of low-income workers and the percent of low-income workers without sick leave.[62] The complete equation is below.

*Benefit = (number of Wx Jobs completed in PY 2008) * (% of WAP households with an employed primary wage earner) * (reduction in missed days work) * (ave. hourly wage) * (8 hours/day)*

The household benefit was calculated by multiplying the product of the above equation by the percent of low-income workers without sick leave. The societal benefit is calculated by multiplying the previously described product by the percent of low-income workers who do have sick leave.

5.2 MA LI SF NEI Study

Answers to these survey questions from respondents living in the cold climate zone were used to estimate this benefit for the cold climate state of Massachusetts (see Table 5.1). The change in missed days at work attributable to weatherization is calculated using Equation 1 discussed in Section 1.2.2:

Equation 1: Change = [(Pre-wx treatment - Post-wx treatment) + (Pre-wx treatment - Post-wx comparison)]/2

Table 5.1. Missed Days at Work: Survey Results

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change
National	7.7 (N=181)	6.9 (N=103)	7.3* (N=202)	0.6
Cold Climate Zone	**10.6 (N=92)**	**4.1 (N=60)**	**9.1** (N=89)**	**4.0**

*** p <.001, ** p<.01, *p < .05

[60] Percent of low -income workers without sick leave: 80%. See: http://www.nationalpartnership.org/site/PageServer?pagename=psd_toolkit_quickfacts
[61] Percent of WAP households with an employed primary wage earner: 34%. The estimate may be under-valued because only one the head-of-household responded to this question.
[62] In 2013, the average hourly wage was $14.32 for a renter. See: http://nlihc.org/oor/2013

The methodology used for the WAP evaluation was modified in several manners to produce an estimate of this benefit for the MA LI SF NEI study.[63] The following bullet documents the adjustments:

- The average estimated hourly wage for a renter (as is assumed in the national methodology) was increased to reflect 2014 wages in Massachusetts: $17.17/hour (increased from $14.32/hour)

5.3 Findings

Table 5.2 below presents the estimates of this impact for the MA LI SF NEI study. The table includes the annual per weatherized unit and the PV of the benefit per unit, assuming a twenty-year life impact of weatherization on this benefit. The results in Table 5.2 can be considered conservative because only one worker per household was included in the benefit calculation.

Table 5.2. Estimated Impact of Fewer Missed Days of Work

	Annual Per Unit Benefit	PV Per Unit Benefit
Households	$149.45	$2,855.21
Society	$37.36	$713.80
Total	**$186.81**	**$3,569.01**

[63] See Table A.5 in Appendix A for more detailed information related to inputs and calculations for impacts of fewer missed days of work.

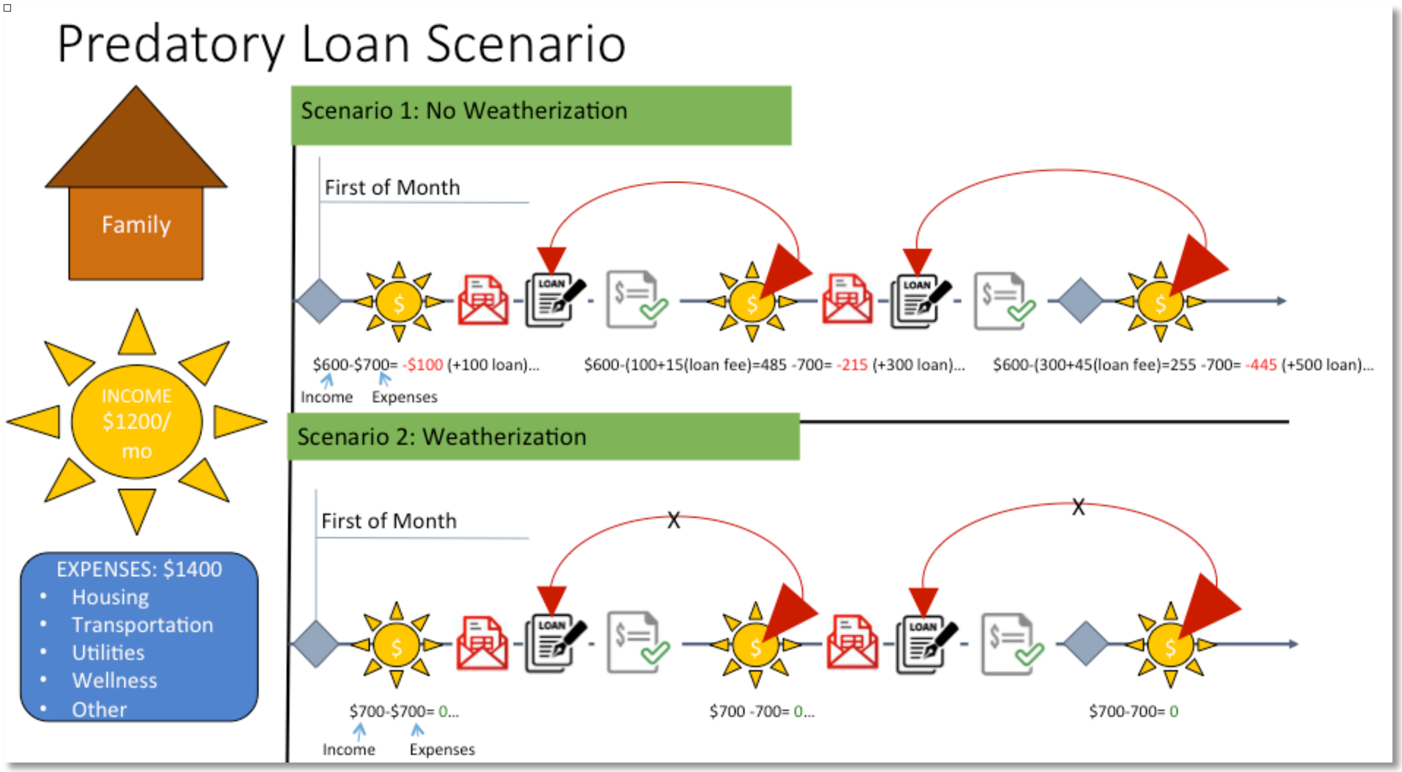
6.0 Reduced Use of Short-Term, High Interest Loans

It is assumed that weatherizing homes and the attendant energy cost savings, water cost savings, and other positive synergistic impacts on households' budgets (e.g., fewer missed days at work, less arrearages, disconnect and re-connection fees) produces a household budget situation where households less frequently find themselves financially tapped when utility and other bills are due. At times, households facing immediate financial stress will seek short-term, high interest loans, such as pay-day or title loans. This is a problem because households have to pay large interest fees that they cannot afford or in some cases, as shown in Figure 6.1, households can quickly see their budget stressors compounding.

This small increase in household income can reduce the need to resort to these high interest loans in order to fund necessary household expenditures, thereby eliminating, or at least reducing, the high-interest fees associated with these loans. Thus, this benefit is not derived from households spending energy cost savings to pay back a loan but rather simply produces a situation where a loan is not required to make ends meet in the first place. For example, assume that weatherization saves the household $400 per year in energy costs. The household can spend these savings in any way, including in ways that yield societal benefits (e.g., able to afford prescription medications which in turn may reduce their consumption of medical insurance). This extra money, combined with even more extra money as discussed above, may allow the household to forgo a pay-day loan to pay for recurring household expense (e.g., rent). If, for example, the interest fee on a $400 pay day loan is $50, then the household has $450 extra to spend, not just $400. The extra $50 in saved interest charges represents a true benefit to the household and does not double count or overlap with the $400 in saved energy costs spent on household expenditures.[64]

[64] It is recognized that this NEI may not be considered a benefit in the current TRC context, though it could be considered if a different cost test were used in the future. Further research may be warranted to examine important positive feedback (i.e., multiplier effects) that weatherization has on household budgets that produce benefits beyond the energy cost savings.

Figure 6.1. Impacts of Predatory Loans on Household Budget



6.1 National WAP Evaluation—Summary of NEI Analysis

From the national Occupant Survey, it was found that fewer households reported experiencing service disconnections, re-connection fees, running out of bulk fuel, and having to pay less than the amount owed on their utility bill. Survey respondents were also asked this question:

In the past year, have you used any of the following to assist with paying your energy bill?

- *a. Payday loan*
- *b. Tax Refund Anticipation Loan*
- *c. Car Title Loan*
- *d. Other type of short term, high-interest loan*
- *e. Pawn shop*

There was an incremental improvement in households not having to resort to using short-term, high-interest loans to make ends meet, with the largest drop being seen in the use of pawn shops. Having more room in the household budget to pay any type of bill seems to have led respondents to make less use of these predatory loans; thereby, reducing the expense of exorbitant loan fees (see Table 6.1) (Pew 2012, Elliehausen 2009; Karger 2004). The national Occupant Survey did not ask households to estimate total annual loan amounts or annual amounts of interest paid by loan category. Background research was conducted to estimate the amounts presented in Table 6.1.

Table 6.1. Estimated Average Magnitude of Annual Short-term, High-Interest Loans per Household[65]

	Amount per Loan	Payments on Interest
Pay Day Loan	$375	$93.75
Tax Refund Anticipation Loan	$500	$125
Car Title Loan	$400	$100
Other types	$350	$87.50
Pawn Shop	$150	$37.50

The total program impact was calculated using this formula:

*Total Impact = (number of Wx Jobs completed in PY 2008) * (percent reduction in households using short-term, high-interest loans) * (reduction in interest payments/loan fees)*

The inputs used in this equation were:[66]

- Percent reduction in households using short-term, high-interest loans: 6.75% (average between all type of loans)
- Average Loan: $335 (Assumed, based on National Occupant Survey results that the typical household makes use of only one loan type per year and only takes out one short-term interest loan per year.)[67]
- Average Interest/Loan Fees: $88.75 (Also assumed that loan was paid back in one month with a 25% monthly interest rate.)

6.2 MA LI SF NEI Study

The change in loan use attributable to weatherization from respondents living in the cold climate zone of the U.S. is presented in Table 6.2.

Table 6.2. Percent Respondents Reporting Household had Used at least One Short-term High Interest Loan in the Previous Year

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change
National	18.6% (N=660)	12.0% (N=392)	11.7%*** (N=797)	6.75%
Cold Climate Zone	**17.5% (N=314)**	**9.2% (N=186)**	**12.9%** (N=327)**	**6.45%**

*** p <.001, ** p<.01, *p < .05

The inputs used for the WAP evaluation were not revised to produce an estimate more tailored to the Massachusetts context.[68] There was insufficient data associated with typical loan amounts

[65] http://www.nclc.org/images/pdf/high_cost_small_loans/ral/report-ral-2011.pdf
http://www.myfoxdc.com/story/17988457/up-to-10-percent-of-virginia-households-use-high-cost-loans#axzz2W7hF0Noh
http://www.businessinsider.com/pawnshop-customers-statistics-2011-11?op=1
http://www.nber.org/papers/w17103.pdf
[66] See Table A.6 in Appendix A for more detailed information related to inputs and calculations for reduced use of short-term, high interest loans.
[67] Less than 5% of respondent households make use of more than one type of these loans per year.

and interest/loans fees at a state or even a regional level. However, data were updated to reflect loan and loan fee amounts for the 2014 timeframe, with the average interest/loan fee adjusted to $73.18. These adjustments resulted in a lower annual and PV per unit benefit than the national evaluation estimates.

6.3 Findings

Table 6.3 presents the estimates of this benefit for the MA LI SF NEI study. This table includes the annual per weatherized unit benefit and the PV of the benefit per unit, assuming a twenty-year life impact of weatherization on this benefit. These results can be considered conservative because the calculation assumes that households did or did not take out a loan (not multiple loans) only one time the past year.[69]

Table 6.3. Estimated Impact of Reduced Use of Short-Term, High Interest Loans

	Annual Per Unit Benefit	PV Per Unit Benefit
Households	$4.72	$90.18
Society	$0	$0
Total	**$4.72**	**$90.18**

[68] See Table A.6 in Appendix A for more detailed information related to inputs and calculations for reduced use of short-term, high interest loans.
[69] It is a conservative assumption that households that do make use of one of these loan types only do so once a year.

7.0 Increased Productivity at Home Due to Improved Sleep

It is assumed that weatherization improves living conditions in homes such that household members get more rest and sleep (e.g., temperatures are more comfortable in the winter and summer, the infiltration of outdoor noise is reduced). The literature supports the assumption that better rest and sleep improves work productivity at jobs outside of the home. It is further assumed from economic theory that productivity of work in the home is also improved. This means, for instance, that a weatherization recipient may be able to clean, cook, and do home maintenance chores more efficiency and effectively. His or her ability to take care of themselves and others in the home (e.g., children, persons of disability, elderly parents) may improve as well. Being more productive at home can benefit the household in many other ways as well. This benefit has a definite labor economic characteristic. While this benefit may be linked in a physical sense to improvements in home comfort and reduced intrusion of outdoor noise, this benefit is not a subjective estimate of how much recipients value feeling more comfortable in their homes or quieter homes. Therefore, this benefit does not double-count willingness-to-pay benefits associated with increased comfort and decreased noise pollution.

7.1 National WAP Evaluation—Summary of NEI Analysis

To explore this societal NEI, the question below was included in the national Occupant Survey. Averaging the change between the treatment group pre-weatherization and the comparison group surveyed in phase 1 and the treatment group pre- and post-weatherization yielded an estimated change of 5.5%.

During the past 30 days, for about how many days have you felt you did not get enough rest or sleep?

This non-energy benefit was quantified as follows:

*Total Program Benefit = (number of Wx Jobs completed in PY 2008) * (percent decrease in at least one bad day of rest/sleep) * (cost per year per employee in productivity losses due to sleep problems/average national hourly wage rate) * wage rate for general housekeepers) * (average hours per week of housework/40 hours per work week)*

The inputs used in this equation are as follows:

- Percent decrease in respondents reporting at least one bad day of rest/sleep in the last thirty days: 5.0%
- Cost in lost productivity per year for employees with sleep problems[70]: $2,500
- Average national hourly wage rate[71]: $22.62
- Average hourly wage rate for general housekeeping[72]: $10.49
- Average hours per week on non-paid housework[73]: 21.5 hours

[70] http://www.businessinsider.com/workers-lack-of-sleep-costs-employers-millions-of-dollars-each-year-2011-1
[71] Bureau of Labor Statistics, August 2010; www.bls.gov
[72] http://www.bls.gov/oes/current/oes372012.htm
[73] (http://www.bls.gov/opub/mlr/2009/07/art3full.pdf)

7.2 MA LI SF NEI Study

As mentioned in the previous section, Occupant Survey respondents were asked how many days in the previous month they had bad rest and sleep. Answers to these survey questions from respondents living in the cold climate zone of the U.S. were used to estimate this benefit (see Table 7.1). The change in bad days of rest/sleep attributable to weatherization is calculated using Equation 1 provided in Section 2.1.2:

Equation 1. [(Pre-Wx Treatment – Post-Wx Treatment) + (Pre-Wx Treatment – Post-Wx Comparison)] / 2

Table 7.1. Percent Decrease in Respondents Reporting at Least One Bad Day of Rest/Sleep in the Previous Month

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change
National	68% (N=650)	65% (N=382)	61% (N=788)**	5.0%
Cold Climate Zone	**68% (N=315)**	**66% (N=181)**	**60%* (N=326)**	**5.0%**

*** p <.001, ** p<.01, *p < .05

The other input used for the WAP evaluation that could be confidently adjusted to produce an estimate of this impact for the MA LI SF NEI study is bulleted below:[74]

- The average estimated hourly wage[75] for work in the home (as is assumed in the national methodology) was adjusted to reflect wages paid to Maids and Housekeeping Cleaners in 2014 in Massachusetts[76]: $12.71 (increased from $10.49/hour)

7.3 Findings

Table 7.2 presents the estimates of this impact for the MA LI SF NEI study. This table includes the annual per weatherized unit and PV of the impact per unit, assuming a twenty-year life impact of weatherization on this benefit. These results can be considered conservative because only one home worker per household was included in the benefit calculation.

Table 7.2. Estimated Impact of Increased Home Productivity Due to Improved Sleep

	Annual Per Unit Benefit	PV Per Unit Benefit
Households	$37.75	$721.26
Society	$0	$0
Total	$37.75	$721.26

[74] See Table A.7 in Appendix A for more detailed information related to inputs and calculations for increased home productivity.
[75] Estimated average hourly wage is unloaded (i.e., wage value does not reflect an organization's overhead or fringe costs).
[76] http://www.bls.gov/oes/current/oes372012.htm

8.0 Reduced Carbon Monoxide Poisoning

Carbon monoxide (CO) is a gaseous compound that results from inefficiently burning carbon-based fuels. These include many common household sources of heat and energy such as natural gas, oil, gasoline, kerosene, coal, wood, etc. Consequences of CO exposure can range from fatigue and nausea for low concentrations to severe poisoning and death for high concentrations. Symptoms of CO poisoning also vary due to length of exposure as well as general health and age of the victim. While proper safety, maintenance, and monitoring can prevent virtually all Unintended, Non-Fire Related (UNFR) CO poisonings, the socio-economic status of low-income households can make such precautions unaffordable. As such, these characteristics could put this population at significantly higher than average risk of UNFR CO poisoning.

8.1 National WAP Evaluation—Summary of NEI Analysis

Through WAP, combustion appliances – furnaces, water heaters, ovens and cooking ranges – are tested for gas leaks and CO emissions during audits and again during final inspections. All detected combustion safety issues are immediately addressed through appliance repairs or replacement. Carbon monoxide (CO) monitors are installed, or expired or defective CO monitors are replaced, in homes that use fossil fuels for heating. Literature provides documentation that the installation of CO monitors reduces incidents of UNFR CO poisonings, which, in turn, reduces ED visits, hospitalizations, and fatalities. This analysis focused on UNFR CO poisonings and on estimating the monetary value to households and society from installing CO monitors in weatherized homes.

As part of the national Occupant Survey, the treatment and comparison groups were asked if anyone in the household had been poisoned by breathing in carbon monoxide, and as a result had to seek medical attention.

Because of the small sample sizes relative to the incidence of CO poisonings and because the research methodologies were not designed to measure lives saved with respect to the installation of CO monitors, the methodology made heavy use of secondary data, along with data associated with the number of CO monitors installed by WAP in 2008.

The monetization of the CO benefit had the following components:

1. The number of ED, hospitalizations and deaths from CO poisoning nationally was estimated;

2. The number of ED, hospitalizations and deaths from CO poisoning potentially prevented by WAP was estimated;

3. Studies that estimated the preventative performance of CO monitors were evaluated;

4. Results from steps 1-4 were combined to estimate the number of ED visits, hospitalizations, and deaths from CO poisoning that could be prevented and attributable to WAP;

5. The monetary values of preventing the ED visits, hospitalizations, and deaths by household and society were estimated utilizing medical costs for the treatment of carbon monoxide poisoning[77]; and

6. Benefits were then divided into household benefits and societal benefits by applying primary payer information from HCUP and MEPS Household Component Event Files.[78] Cases paid by Medicare and Medicaid were considered societal benefits, while uninsured cases were household benefits. Cases whose primary payer was private/other were split between societal and household according to individual out-of-pocket (OOP) payment proportions from MEPS.

CO detectors vary in lifespan according to the model, but they generally remain effective for an average of five years (Rickert 2012; North Shore Fire Department 2011; BRK Brands, Inc. 2011). Therefore, it should be noted that for this NEI, a five-year time period was applied for this benefit rather than the fifteen-year time period applied to all other NEIs.

8.2 MA LI SF NEI Study

Respondents of the Occupant Survey had also been asked if their homes were heated using fossil fuels and, if so, whether they had a CO monitor and, if so, whether the monitor was functional. Answers to the survey questions from respondents living in the cold climate zone of the U.S. were used to estimate this benefit for the cold climate state of Massachusetts. The results are presented in Table 8.1.

[77] Mean medical costs were based on the ICD-9-CM code 986 “Toxic effect of carbon monoxide”. The hospitalization and ED costs were retrieved from an online database provided by the Department of Health and Human Services (DHHS) sponsored by the Agency for Healthcare Research and Quality (AHRQ). The data were collected through the Medical Expenditure Panel Survey (MEPS). (http://meps.ahrq.gov/mepsweb/)

[78] MEPS Household Component Event Files http://meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp

Table 8.1. Decision Matrix for Number of Total Replaceable CO Monitors

Pre-Weatherization Treatment – National (N=665)					
Fossil Fuels as Heating Source?	No 19.8%				
	Yes 80.2% →	**Have CO Monitor? (N=523)**	No 43.8%		
			Yes 56.2% →	**Functional CO Monitor? (N=287)**	No 7%
					Yes 93%
Total Replaceable CO Monitors = 47.64%					
Pre-Weatherization Treatment – Cold Climate Region (N=318)					
Fossil Fuels as Heating Source?	No 13.2%				
	Yes 86.8% →	**Have CO Monitor? (N=272)**	No 37.9%		
			Yes 62.1% →	**Functional CO Monitor? (N=164)**	No 8.5%
					Yes 91.5%
Total Replaceable CO Monitors = 43.03%					

The methodology used for the WAP evaluation was modified in several manners to produce an estimate of this benefit for the MA LI SF NEI study. The following bullets document the adjustments:

- The percentage of weatherized homes using fossil fuels for heating was adjusted to reflect Massachusetts' percentages[79]: 86%
- The average size of households being weatherized was adjusted to reflect cold climate zone rates (Occupant Survey findings): 2.41[80]
- The percentage of homes below 200% of the federal poverty level (FPL) was adjusted to reflect Massachusetts' rates in 2014:[81] 27%[82]
- The average medical costs for ED visits and hospitalizations were adjusted in two steps: 1) national costs to Massachusetts prices for the year 2008, and then 2) the 2008 Massachusetts prices were adjusted to 2014 prices (see Table 8.2). These adjustments

79 http://www.mass.gov/eea/images/doer/energy-dashboard/mass-energy-profile/heating-cooling-chart-2.png

80 In contrast to the other NEIs estimated in this report, we were not limited by survey results to only focus on the respondent; therefore, we are assuming multiple occupants could be at risk in a single household.

81 The threshold for qualifying as a low-income household in MA is higher than the 200% FPL (for a 4-person household, $63,704 in MA based on 60% of state median income vs. $48,600 as 200% of FPL, as shown at http://www.masslegalhelp.org/housing/poverty-guidelines). As a result, these results likely understate the benefits to low-income households in MA.

82 http://kff.org/other/state-indicator/population-up-to-200-fpl/

were based using medical care price indices provided by the U.S. Bureau of Labor Statistics.[83]

Table 8.2. Adjusted Medical Costs for ED visits and Hospitalizations—2008 to 2014

	2008 National	2014 MA	2008 National	2014 MA
Coverage Type	**ED Visits**	**ED Visits**	**Hospitalizations**	**Hospitalizations**
Private Other	$1,337	$2,136	$5,929	$9,475
Medicaid	$842	$1,345	$10,796	$17,251
Medicare	$2,285	$3,651	$11,807	$18,867
Uninsured	$1,203	$1,922	$3,390	$11,542

Due to time constraints, research on updated values of the preventative performance of CO monitors on UNFR CO poisonings was not conducted.

8.3 Findings

Table 8.3 below presents the estimates of this NEI for the MA LI SF NEI study. This table includes the annual impact per weatherized unit and the PV of the impact per unit, assuming a five-year life span of the typical CO monitor. Our analysis also indicates that 0.004 deaths, 0.07 hospitalizations, 0.47 ED visits, are prevented annually per 1000 units weatherized.

Table 8.3. Estimated Impact of Reduced Carbon Monoxide Poisoning[84]

	Annual Per Unit Benefit (5-Year Life)	Annual Per Unit Benefit W/O Avoided Death Benefit	PV Per Unit Benefit (5 Years)	PV per Unit Benefit W/O Avoided Death Benefit
Households	$36.98	$0.25	$183.30	$1.25
Society	$1.87	$1.87	$9.28	$9.28
Total	**$38.85**	**$2.12**	**$192.58**	**$10.53**

The NMR 2011 report does contain an NEI directly related to the reduction of CO poisoning. NMR's benefit was estimated from the installation of new furnaces, which, in turn reduces fire-related CO poisonings. Three[3] estimates only the Unintended and Non-Fire Related CO poisonings prevented by installing new and replacing non-working CO monitors. Therefore, the two methodologies measure two distinctively different NEIs related to weatherization and CO with respect to the causation of CO poisoning.

[83] http://data.bls.gov/timeseries/CUURA103SAM?data_tool=XGtable
[84] For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs was categorized as a societal benefit. For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (i.e., copayments and deductibles) were categorized as a household benefit. For individuals/occupants that are "uninsured," all of the avoided medical costs was categorized as a household benefit.

9.0 Reduced Risk of Fire, and Fire-Related Property Damage

While numerous factors influence home fire occurrence and intensity, certain populations are particularly vulnerable. Persons who are elderly, persons of disability, those that live in sub-standard housing, or are of low socio-economic status have been linked with increases in fire frequency, rates of injury, and fire intensity (Istre, et al. 2001; Shai 2006). As such characteristics are proportionately more common among the population served by low-income weatherization, these applicants are exposed to higher than average home fire risks. These demographic indicators of fire risk often correspond to features of the home and occupant behavior associated with ignition and spread. For example, faulty wiring and unsafe methods of space heating are presumed more prevalent among residents of old homes and those who cannot afford to replace or repair dangerous heat sources. It is well known that weatherization reduces fires and fire damage through the replacement of furnaces, cleaning of dryer vents, and installation of smoke alarms. This section intends to quantify fire risk in homes that are eligible for low-income weatherization services, and to estimate the influence of weatherization on curbing potential for fire damages.

9.1 National WAP Evaluation—Summary of NEI Analysis

The national WAP evaluation Occupant Survey contained three questions that directly address home fires:

I*n the past 12 months how many times has the fire department been called to put out a fire in your home?*

In the past 12 months did any fire start in your home as a result of using an alternate heating source, such as space heaters, electric blankets, your kitchen stove or oven, heating stove, furnace, or your fireplace?

In the past 12 months, how many individuals needed medical attention because of fire?

While these questions address key aspects of fire, several factors restricted their ability to properly gauge fire risk among the WAP population. First, the Occupant Survey's sample size was too small to accurately describe fire frequency and consequence. The national WAP evaluation estimated the likelihood of fire among a population with household income similar to the WAP population. Though households in this sample face a decidedly larger likelihood of fire than the general population, these events occur relatively infrequently with less than four out of one thousand homes catching fire annually. Furthermore, the pre- and post-treatment survey method excluded extreme fire events. Major fire damage in these households could result in an occupant's death, relocation, or deferral of WAP services, which would prevent survey participation.

The WAP evaluation analysis also included estimates of costs related to injuries and deaths of firefighters. These estimates were applied as societal benefits.[85]

Fire risk and prevention among WAP households in single-family buildings followed these steps (Figure 9.1):

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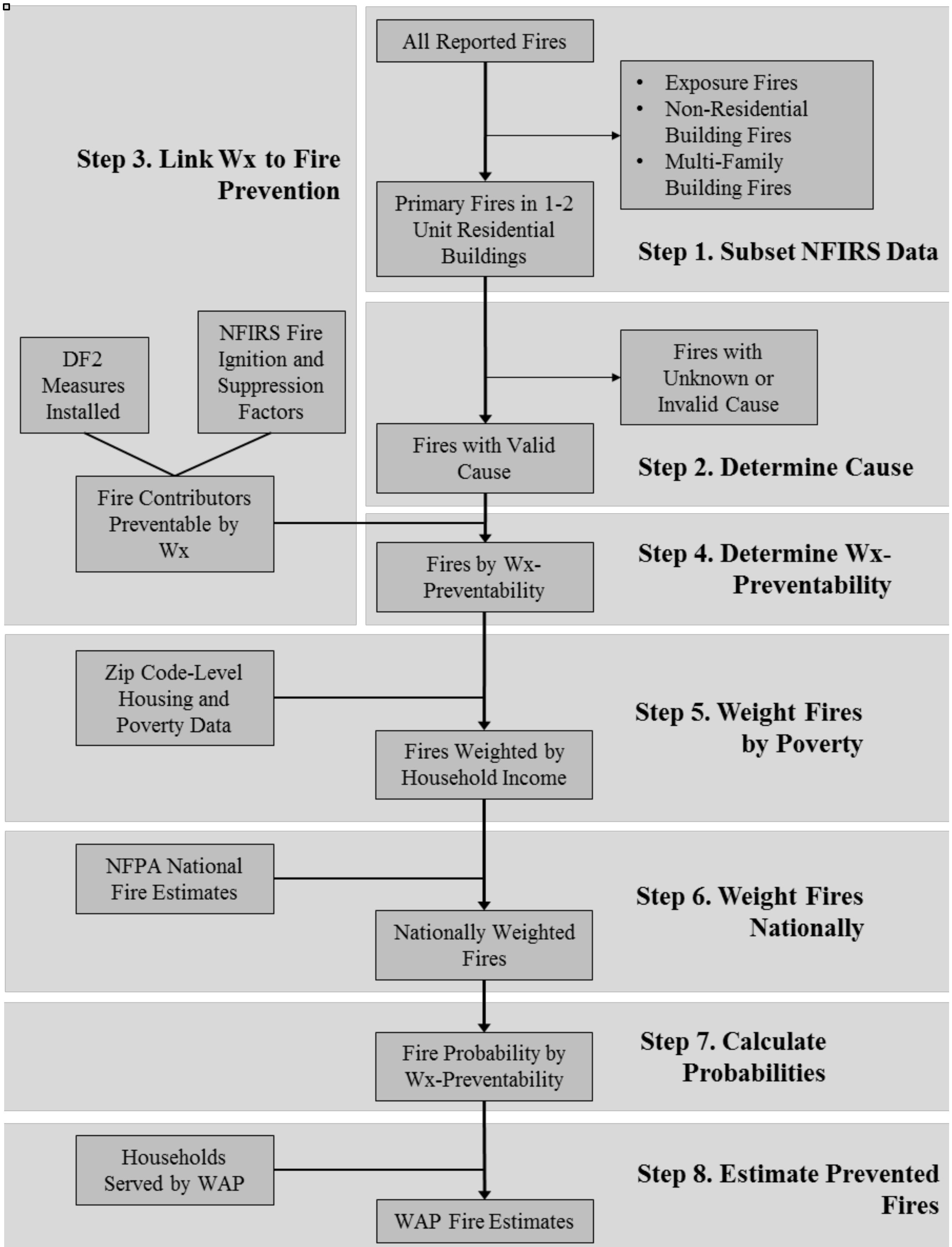
[85] Only firefighter injuries and deaths occurring at the fireground, i.e. the location of a fire incident, were included in the analysis. Valid fireground injury and death cases from the NFIRS Firefighter Casualty module were selected using variables on "where injury occurred" and "activity at time of injury" and merged with the larger dataset.

- National fire data are a subset of the National Fire Incident Reporting System (NFIRS) database that included primary fires in in one- and four-unit residential buildings.[86]
- General causes of these fires were determined and cases with unknown or invalid causes were removed from further consideration.
- Relevant fire incidents were identified by the presence of weatherization-preventable contributors to fire.
- Zip code-level housing and poverty data were matched with each fire to construct sample weights to estimate fire frequency among households under 200 percent of the poverty level.
- Fires and subsequent damages were weighted to estimate national totals.
- Probabilities of fire occurring in WAP homes were estimated using fire incidents and total homes among single-family households whose income was less than 200 percent of the poverty level.
- These probabilities were applied to the 80,352 single-family and mobile homes that received WAP services in 2008.

[86] Fire frequency and fire damage estimates came from the US Fire Administration's (USFA) National Fire Incident Reporting System (NFIRS). NFIRS 5.0 compiled and standardized fire incident data voluntarily reported from approximately 23,000 fire departments in the United States.

Figure 9.1. Overview of WAP Fire Prevention Estimation Methodology



9.2 MA LI SF NEI Study

Energy efficiency programs provided by PAs in Massachusetts install sets of measures comparable to the measures installed by WAP. Many such measures can reduce fire risk thereby reducing property damage in homes, and cases of occupant injury and/or death. From the WAP evaluation, 17 individual or sets of measures were investigated that have been assumed to reduce fire risk and damage (see Table 9.1), and are categorized as either igniters or suppressors. Measures shown to have the most impact on fire risk reduction are: central space heating systems; electrical repair; clothes dryer vent repair/replacement; insulation; and installation/replacement of smoke detectors.

Table 9.1. Select Measures Proven to Reduce Fire Risk and Damage and Estimated Reduction in Risk (in %)

Individual Measures	Benefit %
Igniters	
Electrical repair	16.55
Heating system	20.11
Cooling system	2.87
Clothes dryer vent repair/replacement	11.56
Refrigerator replacement	1.49
Water heater	4.73
Chimney repair	3.52
Fans repair/replacement	2.58
Lighting	2.84
Suppressors	
Smoke alarm installation/replacement	5.87
Windows, doors repair/replacement	2.41
Ventilation	3.68
Air sealing	2.39
Wall insulation	4.27
Roof, attic, ceiling insulation	12.20
Floor insulation	2.07
Gas	0.87

The methodology used to monetize this NEI for the WAP evaluation has been modified in several ways to be applicable for the MA LI SF NEI study. The adjustments to inputs utilized for the WAP model are as follows:

- Reduced fire risk in homes located in cold climate zone based on a range of the measures currently installed or under consideration (all those listed in Table 9.1).
- The average medical costs for ED visits and hospitalizations were adjusted in two steps: 1) national costs to Massachusetts prices for the year 2008, and then 2) the 2008 Massachusetts prices were adjusted to 2014 prices (see Table 9.2). These adjustments were based using medical care price indices provided by the U.S. Bureau of Labor Statistics.[87]

[87] http://data.bls.gov/timeseries/CUURA103SAM?data_tool=XGtable

Table 9.2. Adjusted Medical Costs for Fire-Related Injuries—2008 to 2014

2008	Burn Center	Other Hospital	Emergency Department	Doctor's Office/Clinic
Burns	$26,210	$14,227	$722	$250
Inhalation	$39,592	$8,310	$459	$353
Burn + Inhalation	$72,671	$22,994	$1,433	0
Trauma	$26,813	$26,813	$956	$741
Other	$6,050	$6,050	$548	$336
2014	**Burn Center**	**Other Hospital**	**Emergency Department**	**Doctor's Office/Clinic**
Burns	$41,674	$22,621	$1,148	$398
Inhalation	$62,951	$13,213	$730	$561
Burn + Inhalation	$115,547	$36,560	$2,278	0
Trauma	$42,633	$42,633	$1,520	$1,178
Other	$9,620	$9,620	$871	$534

9.3 Findings

Table 9.3 below presents the estimates of this NEI specifically for low-income weatherization programs in Massachusetts. This table includes benefits both per weatherized unit annually and the PV per unit, assuming persistence of measures for a twenty-year period. Our analysis also indicates that: 0.0087 deaths, 0.013 hospitalizations, 0.4 ED visits, and 0.25 physician office visits, are prevented annually per 1000 units weatherized.

Table 9.3. Estimated Benefit for Reduced Home Fire Occurrences[88]

	Annual Per Unit Benefit	Annual Per Unit Benefit W/O Avoided Death Benefit	PV Per Unit Benefit	PV per Unit Benefit W/O Avoided Death Benefit
Households	$93.84	$9.77	$1,792.84	$186.68
Society*	$17.87	$17.60	$341.39	$336.28
Total	**$111.71**	**$27.37**	**$2,134.23**	**$522.95**

*Note: The avoided injuries and deaths to firefighters are categorized as a societal benefit.

The results in Table 9.3 can be considered conservative because:

- The probability of a fire post-weatherization is assumed to be the average probability of a home fire occurrence, not a lower probability.
- The probabilities of secondary fires were not considered.

[88] For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs was categorized as a societal benefit. For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (i.e., copayments and deductibles) were categorized as a household benefit. For individuals/occupants that are "uninsured," all of the avoided medical costs was categorized as a household benefit.

9.4 Discussion

There is some overlap in the methodologies utilized by Three[3] for the MA NEI study and by NMR, but the efforts were not duplicative. The differences are as follows:

- The NMR estimate is based on preventing fires by replacing furnaces only, whereas the Three[3] estimate is based on preventing fires by the full range of weatherization measures.
- All causes of residential fires were mapped to all commonly installed weatherization measures, including furnace replacement (Three[3]).
- The methodology encompassed national weatherization measure installation rates and also adjusted for poverty levels by zip code (Three[3]).
- As with the other health- and safety-related NEIs discussed in previous sections, the medical cost estimates were broken down into types of coverage in order to bucket benefits as societal and household (Three[3]).

10.0 NMR's Recommendations

In 2011, the NMR Group conducted an evaluation study of non-energy impacts (NEIs) attributable to the Massachusetts (MA) Program Administrators' (PAs') residential and low-income programs that examined a number of health and safety-related benefits to low-income residents. The study included several individual health NEIs that NMR was not able to quantify due to insufficient data, such as reduced asthma, thermal stress and missed days from work (see Appendix A.6 and A.7 for the analysis and discussion).[89] In 2015, an evaluation of the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) was completed that included the assessment and monetization of twelve health and household-related impacts attributable to the weatherization of low-income homes, at a national level.[90,91]

The PAs tasked NMR to review the methodology utilized for the national WAP evaluation, as well as the findings from Three[3]'s MA LI SF NEI study presented in this report. The purpose of this task was to determine the extent to which the NEIs quantified in this WAP-based evaluation overlap with, augment, or supersede the health- and safety-related NEIs previously examined and/or currently claimed by the PAs, and to develop recommendations for integrating the results. At the time of the 2011 NEI report, NMR had noted that several health and safety NEIs, such as heat stress and cold exposure, were being examined by the WAP evaluation and recommended deriving values from the WAP evaluation when it became publicly available.

10.1 Reduced Asthma

The 2011 NMR report estimated an annual overall health NEI for low-income program participants of $19 per low-income participant who installed shell and weatherization measures or heating and cooling equipment based on a survey of program participants. The survey estimated health benefits as reductions in cases or symptoms of the cold, flu, or other illnesses (such as asthma) using the relative valuation method.[92]

NMR recommends that the PAs replace the single health NEI they currently claim with the reduced asthma NEI as well as other health-related NEIs included in this report: reduced thermal stress (see Section 4.0) and fewer missed days of work (see Section 5.0).

There is an extensive literature supporting the positive health impacts of energy efficiency programs through improved home environments (see Section 2.0 of this report, as well as section 5.16 of the 2011 NMR and Tonn et al., 2014, for reviews of the literature). While the NMR study quantified a general health benefit in the form of reductions in cases or symptoms of the cold, flu, or other chronic illnesses such as asthma, the same study found additional, limited, evidence of potential reductions in incidents of seeking medical care for asthma and thermal stress as well as

[89] NMR. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for Massachusetts Program Administrators. (See: http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf)
[90] A complete report presenting findings from this component of the WAP evaluation was published in 2014 and can be found at www.threecubed.org.
[91] A complete description of the methodology is found in: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.
[92] The survey asked respondents if they or anyone in their household experienced a change in the frequency or intensity of colds, flus, and other illnesses, such as asthma or other chronic health conditions, and if so, to quantify the value of that change relative to the estimated energy bill savings attributed to the energy efficiency improvements.

reductions in sick days (see Appendix A.6 and A.7 of the 2011 NMR report). However, because of the extremely small number of respondents reporting *program induced* changes in health, and, in the case of asthma, confounding results, NMR did not recommend estimating NEI values for these additional health benefits. For each health impact, the NMR study found reductions in seeking medical treatment or in the number of sick days among the total low-income study sample, but extremely small numbers of respondents attributed the change to the program.[93]

The WAP study and Three^3's MA LI SF NEI study were better able to detect and quantify these same health impacts because of larger sample sizes and because of the study design that included a pre- and post-weatherization comparison of WAP participants as well as a comparison group of WAP participants that did not rely on respondents assessing the causes of any health impacts identified by the respondent.

There is evidence from the MA LI SF NEI study of reduced urgent care (ED) visits and hospitalizations as well as decreased occurrence of high-cost asthma patients. While not all of the statistical analyses of the changes are statistically significant, the findings consistently find a positive effect from the weatherization and provide evidence for program effects (see Table 3.1-3.3). The evidence from MA LI SF NEI study, the literature (see Section 2.0 as well as NMR, 2011 and Tonn et al., 2014, for reviews of the literature), the NMR relative valuation survey (for general health impacts), and the limited evidence of reduced asthma medical visits from the low-income study population from the NMR study provides evidence of these health impacts.

The NEI monetization method for asthma employed in the MA LI SF NEI study is logical and comprehensive. The sources for medical cost data (Healthcare Cost and Utilization Project (HCUP) and the 2008 Medical Expenditure Panel Survey (MEPS)[94]) and Massachusetts-specific adjustments (the 2014 Costs Trends Report produced by the Health Policy Commission (HPC) and the Center for Health Information and Analysis (CHIA)) are robust and reliable. After removing the portion of the asthma NEI related to indirect costs to avoid double counting of total benefits, NMR believes the asthma NEI estimate presented in this report is the most accurate asthma NEI value available to the PAs at this time. NMR recommends supplanting the currently used overall health NEI estimate of $19 derived from the 2011 NMR study with the total asthma NEI value of $9.99 per household[95] as well as the other health-related NEIs included in this report: reduced thermal stress (10.2) and fewer missed days from work (10.3).

10.2 Reduced Thermal Stress on Occupants

There is evidence from the MA LI SF NEI study for reductions in both heat and cold-related thermal stress, though the evidence for reduced heat-related stress is stronger than the evidence for reductions in cold-related stress. The MA LI SF NEI study found reduced occurrences of both heat- and cold-related thermal stress post-weatherization for both the treatment and the comparison group, though only the difference between the pre and post comparison group for heat-related stress was statistically significant (see Section 4.0). Overall, the evidence from the MA LI SF NEI study, the literature (Section 5.16 of the 2011 NMR report), the NMR relative valuation survey (for general health impacts) and the limited evidence of reduced thermal stress

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[93] These other potential health effects are reported in Appendix A.7 of the 2011 NMR report (NMR. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for Massachusetts Program Administrators)

[94] See Section 4.1 for more detailed information on these sources as provided by Three^3.

[95] As noted earlier in section 10.1, NMR recommends that the PAs replace the single health NEI they currently claim with the reduced asthma NEI as well as other health-related NEIs included in this report: reduced thermal stress (see Section 4.0) and fewer missed days of work (see Section 5.0).

in the total low-income study population from the NMR study (Appendix A.7 in the 2011 NMR report) provides evidence of these health impacts.

The NEI monetization method for heat- and cold-related thermal stress employed in the MA LI SF NEI study is logical and comprehensive. The sources for medical cost data (HCUP and MEPS) and Massachusetts-specific adjustments (U.S. Bureau of Labor Statistics and Kaiser Family Foundation) are reliable. NMR believes the heat- and cold-related thermal stress NEI values presented in this report are the most accurate values available to the PAs at this time. NMR recommends supplanting the currently used estimates of $19 of the health NEI derived from the 2011 NMR study with the cold- and heat-related thermal stress NEI values presented in this report ($463.21 and $145.93, respectively). The substantial increase in the thermal stress NEI is largely attributable to the avoided deaths by reducing the chance of an individual being subjected to dangerously cold or hot temperatures (See Section 4.0 for an overview of the risks of thermal stress).

The risks of thermal stress, including heat and cold-related mortality, are very real and substantial. A recent National Health Statistics Report estimated 2,000 weather related deaths per year in the U.S. from 2006 to 2010 (during the MA LI SF NEI study period) (Barko et al. 2014), with about 31% of these deaths attributed to exposure to heat-related causes and 63% attributed to exposure to excessive cold.The report includes estimates by region, estimating 307 heat and cold related deaths per year in the northeast region. Assuming the deaths are roughly proportionate to the population in each state, there are an estimated 36 cold- and heat-related deaths per year in Massachusetts, 29 of which were cold-related and eight of which are heat-related (See Table 10.1). While not all of these deaths are preventable by weatherization, statistics show that there are enough cold- and heat-related deaths in MA that can be prevented through home weatherization (as shown in Table E.3, a total of about 0.06 lives saved annually per 1,000 units weatherized).

Table 10.1. Estimated Heat and Cold-related Deaths per Year in Northeast States, 2006 to 2010

State	Population (2010)	Percent of Northeast Region	# of Cold-related Deaths per Year	# of Heat-related Deaths per Year
Massachusetts	6,547,629	12%	29	8
Connecticut	3,574,097	6%	16	4
Maine	1,328,361	2%	6	2
New Hampshire	1,316,470	2%	6	2
New Jersey	8,791,894	16%	38	10
New York	19,378,102	35%	85	23
Pennsylvania	12,702,379	23%	56	15
Rhode Island	1,052,567	2%	5	1
Vermont	625,741	1%	3	1
Northeast Region	55,317,240	100%	242	65

10.3 Fewer Missed Days of Work

There is evidence from the MA LI SF NEI study of a decrease in the number of missed days from work post-weatherization, for both the treatment and comparison groups, and the difference between the pre-treatment and post-comparison group was statistically significant (see Section 5.0). Overall, the evidence from the MA LI SF NEI study, the literature, and the limited evidence of reduced sick days in the total low-income study population from the NMR study (see Appendix A.6 of the 2011 NMR study) provides evidence of this health impact.

The NEI monetization method for missed days of work due to illness employed in the MA LI SF NEI study is logical and incorporates Massachusetts-specific hourly wage data. NMR believes the NEI value for missed days of work presented in this report is the most accurate measurement of health benefits associated with missed days of work available to the PAs at this time, and recommends supplanting the currently used health related NEI value estimate of $19 derived from the 2011 NMR study with the missed days of work due to illness NEI value of $149.45 presented in this report. The substantial increase in the NEI is attributable to the MA LI SF NEI study being able to estimate the number of missed days from work (for health-related reasons) and in turn to estimate lost wages whereas the 2011 NMR study relied on a single, self-reported estimate of health impacts.

10.4 Reduced Use of Short-Term, High Interest Loans

The 2011 NMR report examined a number of NEIs that are derived from customer bill savings and did not recommend including any NEIs that are derived from participant bill savings because it could amount to double counting of benefits. Participant bill savings partially overlap with avoided costs accounted for in the Avoided Energy Supply Costs (AESC) in New England (Hornby et al., 2011) and included in the TRC calculations (Hornby et al. 2011). While bill savings and avoided costs partially overlap, they typically differ in part because bill savings are based on average retail savings to participants while avoided costs are based on marginal energy supply costs that are avoided because of the PAs' energy efficiency programs. Theoretically, a participant NEI of bill savings, based on the difference between the avoided energy and capacity costs and participant energy bill savings, could be added to the TRC. However, according to traditional TRC calculation methods,[96] including participant bill savings as a benefit would require including a similar cost in the form of lost PA revenues, thus negating the bill savings benefit. Therefore, there is no additional NEI of participant bill savings

Because the benefit of *reduced use of short-term, high interest loans* is also derived from customer bill savings, NMR does not recommend counting this NEI.

It is also important to note that weatherizing homes reduces energy costs and therefore has positive effects on the household budgets of participating households. This can result in a number of benefits, including but not limited to reduced use of short-term, high interest loans, reduced incidence of service terminations and the costs associated with service termination and reconnection, increased spending on food or medicine, leading to improved health, and reduced need to move or forced mobility. It is possible that the benefits derived from the bill savings have a higher marginal impact on low-income households than the corresponding cost in the form of lost PA revenues. In other words, the benefits derived from bill savings may have a multiplier effect, resulting in more benefits than the associated costs. The PAs could consider further examination of the potential multiplier effect to determine if the benefits accruing to low-income households from bill savings are larger than the corresponding cost in the form of lost PA revenues.

10.5 Increased Productivity at Home Due to Improved Sleep

The 2011 NMR report found that participants in energy efficiency programs that include HVAC components and weatherization measures commonly experience greater comfort due to fewer drafts and more even temperatures throughout the home. The literature provides strong evidence that participants experience increased thermal comfort as a result of programs that affect the heating and cooling of the home, and that they consider these increased comfort levels to be a very important program benefit, both in general terms and in relation to other perception-based NEIs.

Based on the surveys of program participants, NMR recommended an annual value of $101 for low-income participants who installed shell and weatherization measures or heating and cooling equipment.

The MA LI SF NEI study theorized that the NEI of *increased productivity at home* is attributable to making the weatherized homes more comfortable and conducive to better sleep and therefore

[96] Though it should be noted that this NEI might be able to be counted if a different cost test were used in the future.

likely overlaps with the NEI of improved thermal comfort currently claimed by the PAs.[97] Because of the potential overlap, NMR recommends counting half the NEI value for *increased productivity at home* (to an adjusted value of $18.88).

10.6 Reduced Carbon Monoxide Poisoning

The 2011 NMR study quantified several safety-related NEIs attributable to replacing heating systems, including an annual NEI of $6.38 due to avoided deaths attributable to carbon monoxide (CO) poisonings. NMR used the assumptions from the 1993 evaluation of the WAP (Brown et al., 1993), assuming that 100% of CO poisonings attributable to heating systems are avoided.

The NEI monetization method for reduced CO poisonings attributable to CO monitors installed by the program is logical and comprehensive, even accounting for the efficacy of CO monitors in preventing injury and death. The sources for medical cost data (HCUP and MEPS) and Massachusetts-specific data (MA DOER) are reliable. The NEI value accounts for both injury and death resulting from CO poisoning.

The MA LI SF NEI study estimated an NEI of reduced CO poisoning attributable to the CO monitors installed by the program. At the time of the NMR study, the PAs' programs did not install CO monitors, so the benefit currently claimed by the PAs—a portion of the Improved Safety NEI that also accounts for fire-related impacts— is limited to reductions in deaths attributable to CO poisonings avoided by replacing heating systems. NMR believes that Three[3]'s NEI estimate for avoided CO poisoning overlaps with the portion of the Improved Safety NEI that accounts for avoided CO deaths. Although CO monitors and heating systems are mutually exclusive measures, their combined impacts on reduced CO poisonings are not additive. Presumably, the installed CO monitors would prevent nearly all, if not all, CO poisonings that are prevented by a replaced heating system, while also preventing additional CO poisonings attributed to other causes, such as stoves, dryers, heaters and other equipment.

NMR recommends replacing the portion of the Improved Safety NEI attributable to avoided carbon monoxide poisonings ($6.38) derived from the 2011 NMR study with the NEI value from reduced CO poisoning presented by Three[3] in this report ($36.98 annually over the 5-year life of the CO monitor, or one-time 5-year PV of $183.30).

10.7 Reduced Risk of Fire, and Fire-Related Property Damage

The 2011 NMR study quantified several fire safety-related NEIs attributable to replacing heating systems: avoided fire deaths, avoided fire-related injuries, and avoided fire-related property damage.

Reduced incidence of fire (and CO exposure) are commonly identified as safety-related benefits resulting from weatherization programs in the NEI literature. Faulty heating equipment is among the common causes of residential fires (Insurance Information Institute, 1990 as cited in Brown et al., 1993). Additionally, low-income households that cannot afford to pay their heating bills, or have been terminated from service due to nonpayment, have been known to resort to alternative sources of home heating, which are more likely to cause fires and CO poisoning. Similarly,

[97] The WAP study found evidence of overlap between comfort and sleep through their household survey, finding that warmer, less drafty homes were correlated with better sleep. In addition, the study found that bad sleep is positively correlated with bad physical health days, suggesting potential overlap between the WAP health NEIs and increased productivity (as increased productivity is monetized through reducing productivity losses due to sleep problems).

households that have had electric service shut off and resort to candles for lighting are at an elevated risk of experiencing a fire.

The annual NEI values in the 2011 report were estimated using data on the incidence and causes of residential fires and estimates of the avoided costs from fires, including loss of life ($37.40), personal injury ($0.03), and property loss ($1.24).

The MA LI SF NEI study estimated NEI values for the same set of benefits as those currently claimed by the PAs: avoided fire deaths, avoided fire-related injuries, avoided fire-related property damage. The MA LI SF NEI study adopted a more detailed and expanded methodology, including accounting for the impacts of all weatherization measures (rather than limiting to the impacts of heating systems), adjusting fire incidence rates for poverty levels by zip code, included estimates of injuries and deaths for both household and firefighters (societal benefit), and accounting for medical costs covered by insurance and medical costs borne by participants.

NMR recommends that the PAs consider replacing the fire safety-related NEIs they currently claim ($38.67) with 61.25% of the $93.84 in fire safety-related NEIs estimated in this report (i.e., $57.48). The MA LI SF NEI study included measures not currently installed by the PAs programs (e.g., chimney repair), and the 61.25% reflects the reduction in fire risk due specifically to measures installed by the PAs programs, including the safety inspection, replacement, and/or installation of smoke detectors.

10.8 Apportionment of NEI Values to Measures

To estimate NEIs at the measure level, the evaluation team estimated NEIs at the measure level by following the procedures used in the 2011 NMR study. With the exception of CO and Fire, the team assigned a portion of a given NEI value to relevant individual measure based on the average energy bill savings for which the measure was responsible in the 2011 NMR study. As a result, the health-related NEIs are apportioned as follows: air sealing (29.9%), duct sealing (0.7%), heating system (27.7%), insulation (25.1%), pipe wrap (5.5%), service to heating or cooling system (6.1%), programmable thermostat (4.8%) and window replacement (0.08%). The NEI for CO is based on CO monitor installation and therefore the entire value is applied to projects that include safety reviews and installation of CO monitors (see Table 10.2 on the following page for the apportionment of NEIs by measure as well as a comparison of the 2011 NMR and 2016 Three[3] values for each main NEI category). Finally, the analysis in this report is able to estimate the reduction in fire risk on a measure-by-measure basis (see Section 9.0 for more details).

Table 10.2. Apportionment of Household NEI Values to Individual Measures

		NEI Category and Recommended Values ($ per unit)											
		Reduced asthma symptoms	Reduced cold-related thermal stress	Reduced heat-related thermal stress	Fewer missed days at work	Total Health Benefits	Increased home productivity	Total Thermal Comfort (1)	Reduced CO Poisoning	Reduced Home Fires		Total Improved Safety	
	2011 NMR Value					$19.00		$101.00	$6.38 (Annual) (3)		$38.67 (3)	$45.05	
	Recommended Value (Three^3 2016)	$9.99	$463.21	$145.93	$149.45	$768.58	$18.88	$119.88	$183.30 (One-Time)		$93.84	$183.30 One Time for CO Detectors + $57.48 Annual for Fire and Smoke Detectors	
Measure	Percent of Bill Savings used to Apportion Health and Thermal Comfort NEIs (2)	Annual	Annual	Annual	Annual	Annual	Annual	Annual	One-Time	Estimated Risk Reduction (Three^3 2016)	Annual	Annual	
Aerator	0%	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00			$0.00	$0.00	
Air sealing	29.9%	$2.99	$138.66	$43.69	$44.74	$230.08	$5.65	$35.89		2.39%	$2.24	$2.24	
Appliance (refrigerators and freezers)	0%	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00		1.49%	$1.40	$1.40	
Door	0.005%	$0.00	$0.02	$0.01	$0.01	$0.04	$0.00	$0.01			$0.00	$0.00	
Duct sealing	0.7%	$0.07	$3.12	$0.98	$1.01	$5.17	$0.13	$0.81			$0.00	$0.00	
Heating system	27.7%	$2.77	$128.45	$40.47	$41.44	$213.13	$5.23	$33.24		20.11%	$18.87	$18.87	
Hot water system	0%	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00		4.73%	$4.44	$4.44	
Insulation	25.1%	$2.51	$116.41	$36.67	$37.56	$193.15	$4.74	$30.13		18.54%	$17.40	$17.40	
Lighting	0%	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00		2.84%	$2.67	$2.67	
Pipe wrap	5.5%	$0.55	$25.51	$8.04	$8.23	$42.34	$1.04	$6.60			$0.00	$0.00	
Service to heating or cooling system	6.1%	$0.61	$28.33	$8.93	$9.14	$47.01	$1.15	$7.33		2.87%	$2.69	$2.69	
Low flow showerhead	0%	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00			$0.00	$0.00	
Programmable thermostat	4.8%	$0.48	$22.34	$7.04	$7.21	$37.07	$0.91	$5.78			$0.00	$0.00	
Window	0.08%	$0.01	$0.36	$0.11	$0.12	$0.60	$0.01	$0.09		2.41%	$2.26	$2.26	
Total	**100%**	$9.99	$463.21	$145.93	$149.45	$768.58	$18.88	$119.88		55.38%	$51.97	$51.97	Annual for Fire
Smoke Detector Inspection/Replacement/Installation (3)	N/A									5.87%	$5.51	$5.51	Annual for Smoke Detectors
										61.25%	$57.48	$57.48	Annual for Fire + Smoke Detectors
CO Detector Inspection/Replacement/Installation (3)	N/A								$183.30			$183.30	One-Time for CO Detectors
												$36.98	(Annual for CO Detectors, 5 yrs)
									Other Measures to Which the Fire NEI can be Apportioned:				
									Electrical repair	16.55%	$15.53		
									Clothes dryer vent repair/replacement	11.56%	$10.85		
									Chimney repair	3.52%	$3.30		
									Fans repair/replacement	2.58%	$2.42		
									Ventilation	3.68%	$3.45		
									Gas	0.87%	$0.82		

Notes:

(1) The revised value reflects NMR's 2011 estimate of $101 for Thermal Comfort plus half of Three^3's estimate for Increased Home Productivity (one-half of $37.75, or $18.88) to account for potential overlap.

(2) With the exception of Reduced CO Poisoning and Reduced Home Fires, the NEIs are apportioned based on the relative percentages of the average bill savings across those measures that are relevant and applicable to each NEI, as analyzed and computed in the 2011 NMR study.

(3) NMR's 2011 estimate for the Improved Safety NEI ($45.05) was based on an analysis of avoided deaths from fire-related CO poisonings ($6.38) and avoided fire deaths, injuries, and property damage (totaling $38.67) due to heating system replacement only. On the other hand, Three^3 is able to estimate the reduction in fire risk on a measure-by-measure basis, the results of which are reflected above. The revised NEI for CO Poisoning is based on CO monitor inspection/replacement/installation and therefore applies as a whole to each measure that involves the safety review, replacement and/or installation of CO monitors (i.e., is not apportioned among measures). The portion of the NEI for Reduced Home Fires attributable to smoke detectors ($5.51) is to be applied to each measure that involves the safety review, replacement and/or installation of smoke detectors.

Table 10.3 presents a comparison of the 2011 NMR and 2016 Three^3 values for each main NEI category as well as for two key measures, Weatherization and Heating System Retrofit/Replacement, on both an annual and 20-year PV basis.

Table 10.3. Comparison of 2011 NMR and 2016 Three^3 NEI Values ($ per unit)

	Annual		NPV (20 Yrs at 0.44%)	
	NMR 2011	Three^3 2016 (1)	NMR 2011	Three^3 2016 (2)
By NEI Category				
Health Benefits	$19.00	$768.58	$363.00	$14,683.78
Thermal Comfort	$101.00	$119.88	$1,929.61	$2,290.22
Improved Safety	$45.05	$94.46	$860.68	$1,281.40
By Key Measure				
Weatherization, electric or gas (3)	$10.46	$551.37	$199.84	$10,010.70
Heating System Retrofit/Replacement, electric or gas (4)	$50.32	$307.73	$961.37	$5,355.98

Notes:
(1) Three^3 2016 annual NEI estimate for Improved Safety, Weatherization, and Heating System Retrofit includes annual estimate for CO monitors of $38.67 (5-year life).
(2) Three^3 2016 NPV NEI estimate for Improved Safety, Weatherization, and Heating System Retrofit includes 5-yr (not 20-yr) NPV estimate for CO monitors of $183.30.
(3) Weatherization includes Health, Thermal Comfort, and Safety NEIs apportioned for air sealing, insulation, smoke detectors, and CO detectors.
(4) Heating System Retrofit/Replacement includes Health, Thermal Comfort, and Safety NEIs apportioned for heating system, smoke detectors, and CO detectors.

As shown in Table 10.3 the differences between the two sets of results are substantial. The reasons for these substantial differences are as follows:

- The NMR estimates were based on the survey (post-weatherization only) respondents' ability to recognize and report health effects monetized by their willingness to pay for improved health and comfort *relative to their energy bill savings*, whereas the Three^3 estimates are based on the Occupant Survey respondents' self-reported changes in health and household status (as measured from pre- to post-weatherization with a comparison group) and monetized using a more robust set of secondary data of national and state medical incidence (e.g., applicable types of medical treatment sought) and cost (e.g., by type of insurance coverage and treatment).
- The sample size of the Occupant Survey was substantially larger, increasing Three^3's ability to detect rare events such as the need for medical care and potential number of deaths due to thermal stress that could be avoided from weatherization.
- In the Three^3 analysis, the relatively few number of avoided deaths due to thermal stress, CO poisoning, and fire could therefore be monetized assuming a VSL of $9.6 million, which substantially increases the per unit value of the NEIs from the corresponding NMR estimate.

- NMR's survey questions referenced multiple health benefits collectively (colds, flus, asthma, and other chronic health conditions), whereas the Occupant Survey questions targeted each potential health benefit separately (asthma, thermal stress).
  NMR could estimate the benefit of improved safety from reduced CO poisoning and fires due to a single measure only (heating system retrofit/replacement), whereas Three[3] could estimate this benefit from a wider range of measures using a more robust set of secondary data of national and state CO and fire incidence.

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Appendix

Table A.1. Inputs and NEB Estimates for Thermal Stress-Cold

Thermal Stress-Cold			
Self-reported decrease in medical care for thermal stress due to weatherization (WAP occupant survey - cold climate zone)	1.9%		
	Office Visits	ED Visits	Hospitalizations
Insurance coverage ratio, specific to ICD-9 diagnostic codes, for payment of treatment type a, b, and c (*adjusted for MA LI population)			
Medicare	21%	22%	60%
Medicaid	11%	20%	23%
Private/Other	56%	22%	10%
Uninsured	11%	37%	7%
Percent of medical cost that is out-of-pocket (OOP) for Private/Other ONLY	10.34%	8.87%	3.26%
Percent of medical care for thermal stress (national rate)	50.1%	39.9%	10.0%
Reduction in medical care visits due to weatherization, per 1,000 weatherized units	9.5	7.6	1.9
Average Medicare cost (MA-adjusted, 2014)	$185.12	$1,069.59	$13,700.80
Average Medicaid cost (MA-adjusted, 2014)	$132.79	$419.41	$19,111.45
Average Private/Other cost (MA-adjusted, 2014)	$321.68	$1,577.17	$16,249.09
Average Uninsured cost (MA-adjusted, 2014)	$114.70	$870.02	$11,671.41
Household NEB$, per weatherized unit, per year (OOP costs)	**$0.30**	**$2.65**	**$1.72**
Societal NEB$, per weatherized unit, per year	**$2.06**	**$4.78**	**$26.90**

Table A.2. Inputs and NEB Estimates for Thermal Stress-Hot

Thermal Stress- Hot			
Self-reported decrease in medical care for thermal stress due to weatherization (WAP occupant survey - cold climate zone)	**2.80%**		
	Office Visits	**ED Visits**	**Hospitalizations**
Insurance coverage ratio, specific to ICD-9 diagnostic codes, for payment of treatment type a, b, and c (*adjusted for MA LI population)			
Medicare	21.3%	25.0%	65.5%
Medicaid	11.5%	16.5%	10.2%
Private/Other	55.9%	25.5%	18.4%
Uninsured	11.3%	32.9%	5.9%
Percent of medical cost that is out-of-pocket (OOP) for Private/Other ONLY	10.3%	8.9%	3.3%
Percent of medical care for thermal stress (national rate)	11.5%	84.5%	4.0%
Reduction in medical care visits due to weatherization, per 1,000 weatherized units	3.2	23.6	1.1
Average Medicare cost (MA-adjusted, 2014)	$185.00	$1,070.00	$9,169.00
Average Medicaid cost (MA-adjusted, 2014)	$133.00	$419.00	$12,400.00
Average Private/Other cost (MA-adjusted, 2014)	$322.00	$1,577.00	$7,515.00
Average Uninsured cost (MA-adjusted, 2014)	$115.00	$870.00	$7,726.00
Household NEB$, per weatherized unit, per year (OOP costs)	**$0.10**	**$7.62**	**$0.56**
Societal NEB$, per weatherized unit, per year	**$0.70**	**$16.65**	**$9.64**

Table A.3. Inputs and NEB Estimates for Avoided Deaths Related to Thermal Stress-Cold

Avoided Deaths: Thermal Stress-Cold	
Percent of hospitalizations from thermal stress resulting in death (national rate)	2.511774%
Rate of reduction in thermal stress deaths due to weatherization	0.00477237%
Reduction in thermal stress deaths per 1,000 weatherized units	0.047723705
VSL (USDOT)	9,600,000
Household avoided death NEB$, per weatherized unit, per year	**$458.54**
Total Household NEB$, per weatherized unit, per year	**$463.21**
Total Household NEB$ without avoided deaths, per weatherized unit, per year	**$4.67**
Total Societal NEB$, per weatherized unit, per year	**$33.73**
Discount rate (real)	0.0044
Life of benefit (years)	20
Household NEB$, PV per weatherized unit	**$8,849.71**
Household NEB$, PV per weatherized unit (without avoided deaths)	**$89.30**
Societal NEB$, PV per weatherized unit	**$644.47**

Table A.4. Inputs and NEB Estimates for Avoided Deaths Related to Thermal Stress-Hot

Avoided Deaths: Thermal Stress-Hot	
Percent of hospitalizations from thermal stress resulting in death (national rate)	1.28%
Rate of reduction in thermal stress deaths due to weatherization	0.00143382%
Reduction in thermal stress deaths per 1,000 weatherized units	0.014338224
VSL (USDOT)	$9,600,000
Household avoided death NEB$, per weatherized unit, per year	**$137.65**
Total Household NEB$, per weatherized unit, per year	**$145.93**
Total Household NEB$ without avoided deaths, per weatherized unit, per year	**$8.28**
Total Societal NEB$, per weatherized unit, per year	**$27.00**
Discount rate (real)	0.0044
Life of benefit (years)	20
Household NEB$, PV per weatherized unit	**$2,787.95**
Household NEB$, PV per weatherized unit (without avoided deaths)	**$158.19**
Societal NEB$, PV per weatherized unit	**$515.86**

Table A.5. Inputs and NEB Estimates for Missed Days of Work

Missed Days of Work	
Self-reported decrease in missed work days due to weatherization (WAP occupant survey - cold climate zone)	4
Percent of LI households with an employed primary wage earner	34.0%
Average hourly wage (renter, MA-adjusted to 2014)	$17.17
Work hours per day	8
	$186.81
Percent of LI workers without sick leave (national)	80.0%
Total Household NEB$, per weatherized unit, per year	**$149.45**
Percent of LI workers with sick leave	20.0%
Total Societal NEB$, per weatherized unit, per year	**$37.36**
Discount rate (real)	0.0044
Life of benefit (years)	20
Household NEB$, PV per weatherized unit	**$2,855.21**
Societal NEB$, PV per weatherized unit	**$713.80**
Total NEB$	**$3,569.01**

Table A.6. Inputs and NEB Estimates for Short-Term, High Interest Loans

Short-Term, High Interest Loans	
Self-reported decrease in use of short-term, high interest loans due to weatherization (WAP occupant survey - cold climate zone)	6.45%
Average interest/loan fees (national, 2014-adjusted)	$73.18
Total Household NEB$, per weatherized unit, per year	**$4.72**
Discount rate (real)	0.0044
Life of benefit (years)	20
Household NEB$, PV per weatherized unit	**$90.18**

Table A.7. Inputs and NEB Estimates for Increased Productivity at Home Due to Improved Sleep

Increased Home Productivity	
Percent increase in respondents reporting no sleep problems in the last 30 days	5.0%
Cost in lost productivity per year for employees with sleep problems	$2,500
Average national hourly wage rate	$22.62
Average hourly wage rate for general housekeeping (MA-adjusted, 2014)	$12.71
Average hours per week on non-paid housework (BLS)	21.5
No. of hours per work week	**40**
Total Household NEB$, per weatherized unit, per year	**$37.75**
Discount rate (real)	0.0044
Life of benefit (years)	20
Household NEB$, PV per weatherized unit	**$721.26**

Project R4 HES/HES-IE Process Evaluation and R31 Real-time Research

FINAL

April 13, 2016

SUBMITTED TO:
Connecticut Energy Efficiency Board, Eversource, and United Illuminating

SUBMITTED BY:
NMR Group, Inc.

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AB Abstract

The R4 Project assessed the Home Energy Solutions program (HES) and HES Income Eligible program (HES-IE). The primary analyses examined the processes, short-term persistence, net-to-gross, non-energy impacts, health and safety, contractor development, and database and document quality of HES and HES-IE. Three related projects were conducted jointly with the R4 analysis: R46, which drilled down on decision making and financing associated with the program; R152, which assessed how effective the Connecticut Clean Energy Communities (CEC) program is at driving greater participation in HES; and R31, which piloted the effectiveness of performing participant surveys (for HES, in this pilot) closer to dates of participation.

Program process. When it came to program processes, the study found that HES and HES-IE participant satisfaction was high (4.2 and 4.0, respectively, out of 5), and program awareness among non-participants was moderately high (15-26% unaware). Word of mouth, utility outreach, and Community Action Agencies were the most effective marketing approaches for HES participants (32%, 13%, and 12%) and HES-IE participants (23%, 10%, and 22%, respectively). The ease of applying for the program was ranked highly (4.4), but rankings of the speediness of incentives (3.9) and financing application process (3.6) were lower. Participants were motivated to participate out of a desire to save energy and energy costs—and, in fact, many reported saving energy as a result of the program. Nonparticipants were held back from participating because they did not or could not prioritize energy efficiency. In a few cases, HES-IE landlords and property managers expressed some dissatisfaction because the participation process took longer than they expected or they had issues with program communication.

Decision making and financing. Participants preferred program rebates over financing opportunities, expressing aversions to financing, perceiving that there was not a need for it, or—in contrast—finding the financing amounts inadequate. When they were interested in financing, customers were attracted to zero percent loans and on-bill financing. Incentives appeared to be pivotal in the decision-making process and many desired that they cover roughly one-half of project costs.

Vendors actively promoted program rebate and financing opportunities, and awareness of these offerings was high among nonparticipants, especially when compared to a similar program in the Northeast. Vendor recommendations did not always lead to installs, but their post-assessment follow-up may be linked to insulation upgrades. Financing materials and processes confused some vendors and customers despite the fact that the evaluation team assessed that program financing materials were extensive and clear (with only some concern that sources used varied nomenclature).

Short-term persistence. On-site persistence visits to HES-IE multifamily buildings found that portable measures exceeded counts in program data, but also found that there was limited measure removal. The removals at those sites were most often due to breakage. According to end-users, light bulb removals most often resulted from respondent dissatisfaction.

Net-to-gross (NTG). The study estimated an HES free ridership rate of 0.22 and a spillover rate of 0.02, resulting in a weighted NTG ratio of 0.80 for the HES program. Based on sample sizes and confidence intervals, the study suggests updating the program savings document free ridership rates for insulation (0.06), water saving measures (0.20), and water pipe wrap (0.28). Free ridership for insulation was notably low (0.06), signaling its importance to the program.

Non-energy impacts (NEIs). Participants experienced positive net impacts from program NEIs, and in comparison to neighboring Northeast programs, they valued program NEIs relatively highly, as well. The vast majority of participants reported positive net impacts—valuing comfort, safety, and property value improvements the most. While nonparticipant end-users were not very aware of possible NEIs, landlords and property manager participants were driven, in part, to participate because of possible NEIs.

The analysis found overall NEI values of 0.87 for HES end-users, 0.90 for HES-IE end-users, and 0.73 for HES-IE landlords and property manager participants. Adding the end-user NEI values to the programs' total resource benefit-cost ratios could mean increases in program total resource benefits of $155.6 million for HES (45% increase) and $95.6 million for HES-IE (64% increase) over the 2016 to 2018 program period.

Health and safety. Vendors cited health and safety issues as major barriers to participation. Participants reported that assessors found some health and safety issues, most often discovering asbestos and vermiculite insulation and knob and tube wiring. Customer remediation of these issues were hindered by cost.

Connecticut contractor development. While not always the case, vendors said that their businesses' viability largely depends on the existence of HES, reporting that the program increased their revenue and staffing levels and helped expand their energy efficiency business. They also observed that the program had expanded the general market for energy efficiency services, but they were skeptical that HES, in particular, would continue to grow.

Connecticut Clean Energy Communities. Statistical analyses failed to find a consistent relationship between CEC program outreach, HES participation, and deeper-measure uptake. However, interviewees reported the effectiveness of 1) leveraging community events 2) the existence of a core group of motivated community members to spearhead community engagement, and 3) the excellent utility staff support that they received that all contributed to CEC success.

Program documentation. Observations from the document review indicated that program materials were, for the most part, clear, easy to understand from the customer perspective, and contained useful resources for vendors. Participant and vendor feedback, in contrast, implied that program actors may need even clearer/more comprehensive resources—especially, when it came to financing information.

ES Executive Summary

NMR Group, Inc., and its partner The Cadmus Group were contracted by the Connecticut Energy Efficiency Board (EEB) to conduct a process evaluation of its Home Energy Solutions (HES) and HES Income Eligible (HES-IE) programs—known as the R4 Project. This evaluation included assessments of program processes, short-term persistence, net-to-gross analysis (NTG), non-energy impacts (NEIs), health and safety concerns that could limit service provision, contractor development, and database and document quality. The EEB also contracted the evaluation team to conduct a separate study (R31), included in this report, which piloted the effectiveness of performing participant surveys addressing program processes and decision making in a timeframe closer to their dates of participation. The R31 study addressed not only HES and HES-IE, but also end-user rebates obtained outside of HES. Finally, the report also includes two additional projects leveraged with R4 and R31: the R46 Project, which examined decision making and financing, and the R152 Project, which assessed the impact of the Connecticut Clean Energy Communities (CCEC) program on HES participation and deeper-measure uptake.

These four studies collectively included eight modules that focused on critical issues related to HES, HES-IE, rebate programs, and the CEC program. Table 1 outlines the modules and their objectives and research questions, while Table 2 maps each module to the research tasks designed to answer these questions.

While this report assumes that readers have some familiarity with four programs described in this study, brief descriptions are as follows:

- **Home Energy Solutions** is the “flagship” program funded by the Connecticut Energy Efficiency Fund (CEEF). Program vendors perform energy assessments of single-family and multifamily residences, providing “core services” measures such as efficient light bulbs, faucet aerators, showerheads, air sealing, and duct sealing for a nominal fee (currently $99). Vendors provide recommendations to participants on add-on measures that are not core services that they could adopt to achieve deeper energy savings. These measures are usually eligible for rebates, zero- or low-interest program financing, or both.
- **Home Energy Solutions – Income Eligible** shares many characteristics with HES, but services are limited to low-income households. Participating households receive the same core services as in HES, but they are not subject to a co-pay; add-on measures are generally provided for free to owner-occupants, although landlords may be subject to co-pays. The list of add-on measures differs somewhat between HES and HES-IE (e.g., HES-IE does not include central air conditioning), and some HES-IE participants simultaneously receive services from the Department of Energy’s Weatherization Assistance Program (WAP).[1]

[1] Exploring and explaining the criteria for which participants receive WAP services is beyond the scope of this study, but involves a mixture of eligibility for other social services and fuel assistance programs and availability of WAP program funds.

- **Rebates** are available for some measures outside of the HES and HES-IE umbrella. For example, households could adopt central air conditioning or ductless heat pumps without going through the HES programs. Participants buy these measures on their own or through a contractor and submit forms for a rebate. The study did not examine any upstream rebate programs (e.g., those for lighting, water heating, and other measures) in which rebates go to manufacturers, retailers, or contractors.
- **Clean Energy Communities** works with community groups to promote energy efficiency and renewable energy in towns across Connecticut. Towns sign Clean Energy Communities Municipal Pledges and engage in outreach activities that encourage energy efficiency and renewable energy in municipal buildings, residences, and small businesses. Towns earn "points" based on the number of participants and the types of measures they install. Once they have earned 100 points, towns are eligible to apply for grants to fund additional energy-efficiency and renewable energy projects.

Table 1: Research Modules, Objectives, and Questions

Module	Major Objectives / Research Questions
Module 1: Program Processes, Experience	Program awareness, experience, satisfaction; clarity of program materials; wait time for receiving services
Module 2: Health and Safety	Degree to which health and safety concerns limit services; types of concerns found; mitigation of health and safety concerns
Module 3: Decision making and Financing (Study R46)	Awareness / use of rebates, financing; role of rebates, financing in decision to install measures; ease of applying for rebates, financing; vendor experience promoting rebates, financing
Module 4: Non-energy Impacts	Whether participants experience non-energy impacts; which they experience; value placed on impacts; impacts expected by non-participants; vendor discussion of impacts
Module 5: Net-to-Gross Ratios	Likelihood of purchasing measures without program incentives; additional purchases made because of program experience
Module 6: Persistence and Effective Useful Life	On-site verification of persistence of portable measures in HES-IE multifamily buildings; self-reported persistence of additional measures (via telephone); early check-in for effective useful life (EUL) where appropriate
Module 7: Connecticut Contractor Development	Degree to which program has increased revenue, staff for program vendors and energy-efficiency service providers more generally; degree of reliance on HES for work
Module 8: Clean Energy Communities (Study R152)	Degree to which activities performed through the Clean Energy Communities Program induces participation in HES and uptake of deeper measures

Table 2: Mapping of Study Modules and Tasks

	Task 1: Participant and Nonparticipant Surveys	Task 2: HES-IE Multifamily Landlord Interviews	Task 3: On-site Visits	Task 4: Program database review	Task 5: Program document review	Task 6: Bench-marking	Task 7: Vendor Interviews	Task 8: CCEC in-depth interviews and database analysis
Sample Size	*R4 Parts = 833* *R31 Parts = 299* *R4 Non-parts = 240*	*30*	*Sites = 13* *Units = 86*	*N/A*	*N/A*	*N/A*	*23*	*6*
Module 1: Process and Experience	X	X	X	X	X	X		
Module 2: Health & Safety	X	X					X	
Module 3: Decision making, Financing	X	X			X	X	X	
Module 4: Non-energy Impacts	X	X			X	X	X	
Module 5: Net-to-Gross	X	X				X		
Module 6: Persistence & EUL	X	X	X			X		
Module 7: Connecticut Contractor Development							X	
Module 8: CEC Impact on HES								X

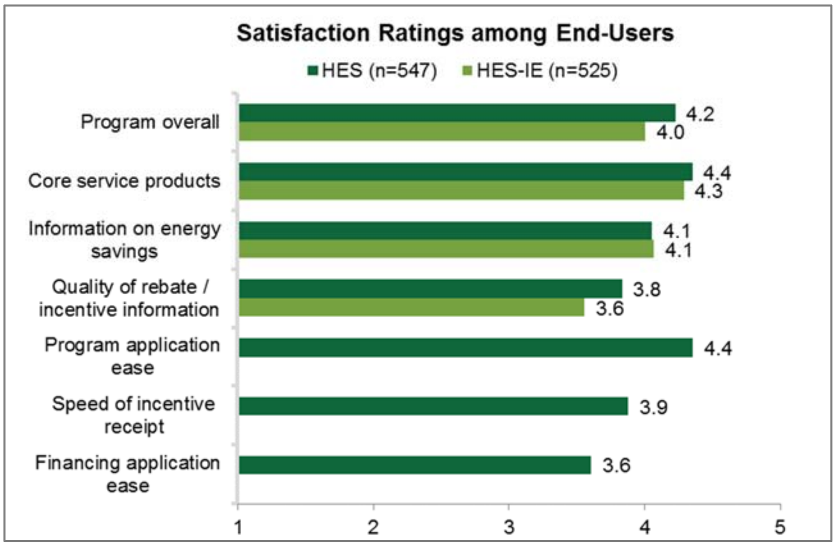
Findings

The following are the R4 study's major findings on the key topic areas.

Executive Summary – Program Processes

The study examined program processes using nearly all research tasks, except vendor and CEC-focused interviews. The primary findings from the exploration of the program processes include the following:

- **Satisfaction is high.** End-users were highly satisfied with the program overall, in particular with core services and add-on measures. However, some expressed disappointment with the quality of rebate and incentive information. Landlords and property managers were highly satisfied, particularly with vendors, add-ons, and assessment reports.



- **Program awareness is moderately high.** Both rebate-only participants[2] and customers who responded to the nonparticipant survey reported moderately high awareness of the programs.
- **Word of mouth and utility outreach are effective marketing approaches**. End-user participants most often learned about the program through word of mouth and learned of rebates and incentives for the first time during the assessments. Rebate-only end-users most often learned of program rebates through their installation contractors or vendors. Nonparticipant end-users learned of the program through word of mouth, bill inserts, and other utility advertisements. Landlords and property managers usually learned about it through utility outreach.

[2] End-users that did not participate in HES or HES-IE but received program rebates for installing measures

- **Desire to save energy and energy costs drives participation.** End-user participants were driven to participate in order to identify ways to save money on energy costs and to learn about energy-saving opportunities. Reducing their own and/or their tenants' energy bills was a top driver of landlord and property manager participation.
- **Nonparticipants do not or cannot prioritize energy efficiency**. Nonparticipant end-users do not participate because they have not made energy efficiency a priority, do not see a need, or find the cost prohibitive.
- **Many participants observe energy savings.** Most end-user participants self-reported reductions in energy consumption, with HES end-users citing an average decrease of 10% and HES-IE end-users stating an average decrease of 9%.
- **Participants offer a variety of suggestions for program improvements.** End-user participants suggested improving program work quality and information, expanding offerings, and increasing advertising. HES-IE landlords and property managers suggested that the program communicate better, increase incentive amounts, and improve the quality of core services.

Executive Summary – Decision Making and Financing (R46)

The R46 study, an expansion of R4 and R31, assessed decision making and financing through the use of computer-assisted telephone interviewing (CATI) surveys with HES participants and nonparticipant end-users, and in-depth interviews with HES-IE landlords/property managers and HES vendors.[3]

Preferences

- **Participants prefer rebates to financing.** Vendors generally found that participants prefer rebates as opposed to financing, observing their participating customers positively reacting to rebate opportunities—and being overwhelmingly enthusiastic about the amount of the insulation rebate.
- **Participants want rebates that cover roughly one-half of project costs.** On average, HES end-users who did not install all of the recommended improvements estimated that they would need close to one-half (48%) of the cost of upgrades to be covered by program rebates and incentives to be enticed to move forward with all of the recommended improvements. In that same vein, vendors' observations of customers' enthusiasm for the insulation rebates was driven by the portion of the cost that insulation rebates cover (up to 50% of the cost).
- **Zero percent loans and on-bill financing are attractive.** Despite their preferences for rebates and incentives, landlords and property managers speculated that if they used any type of financing for energy-saving upgrades they would use utility low-interest loans or, if available, on-bill financing. Additionally, participant end-users who did not use financing nevertheless considered the zero percent loans to be the most attractive possibility.

Barriers to participation in the financing option

- **Some customers remain averse to financing.** While participants may find zero percent loans and on-bill financing attractive, vendors still encounter many participants who are simply averse to financing no matter the structure. Nonparticipant end-users echoed this, with an aversion to debt being among the most common reasons given for not applying for financing support for upgrades they made on their own. Participating end-users also frequently cited an aversion to incurring debt as a reason they decided not to use financing.
- **Lack of perceived need also detracts from partaking in financing.** Most commonly, HES end-users that had made energy saving improvements have not or will not apply for rebates or incentives for the additional improvements because they believe they already have sufficient funds—they will not be "free riding." Non-low income (NLI)[4] nonparticipating end-users, regardless of whether or not they had

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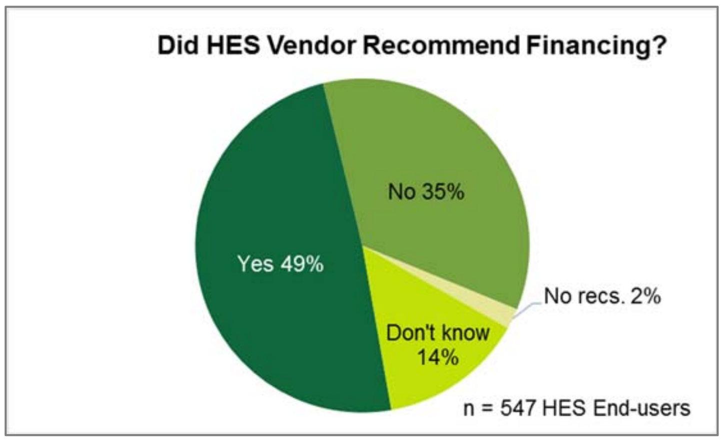
[3] This analysis is meant neither to compare and contrast the financing or rebate options nor to make specific recommendations on rebate amounts or financing interest rates and terms. Instead, the study shares the experiences, preferences, and observations of program participants and vendors.
[4] CATI survey questions determined if a respondent was low-income if their responses confirmed that their income was less than 80% of the area median income as reported by U.S. Department of Housing and Urban Development: https://sites.google.com/site/connecticutmortgagelimits/hud-median-income-limits.

installed energy-efficiency measures also commonly reported not wanting financing because they already had sufficient funds to make the improvements. Similarly, HES-IE landlords and property managers often responded that they would not need financing because their operating or reserve budgets could support the upgrades.

- **Financing is appealing but still not enough for some.** The issue of still not having enough funding to cover down payments was the most common reason why low-income nonparticipants did not apply for financing options. HES-IE landlords and property managers added that the long-term cost of paying off loans would still be out of their budgets.

Awareness of program rebates, incentives, and financing

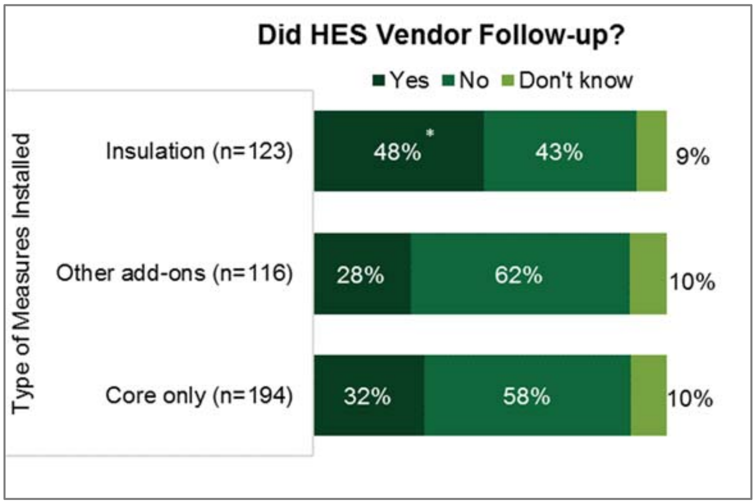
- **Vendors actively promote program opportunities.** According to themselves and participants, vendors actively promote utility rebates, incentives, and financing. Vendors most often reported recommending CHIF loans, Smart-E Loans, and on-bill financing; they said their emphasis is on zero percent financing and on-bill repayment opportunities, but they try not to be invasive or "pushy" about these opportunities.
- **Awareness is high among nonparticipants.** Nonparticipant end-users expressed considerably high awareness of utility financing and rebates, especially when compared to a similar program in the Northeast.



Pivotal decision-making factors

- **Incentives appear to be pivotal in the decision-making process.** HES-IE landlords and property managers greatly value incentives in their decisions to install add-on measures, along with energy bill savings and return on investment. Additionally, the majority of nonparticipant end-users that had not been very aware of them thought that rebates would influence them to move forward if they knew more about the rebates. This finding must be interpreted with caution as relatively low rates of rebate use among HES participants casts doubt on whether nonparticipants actually would follow through if given the opportunity.
- **Vendor recommendations do not always lead to installations.** Vendors provide recommendations on additional improvements to the majority of HES end-users, but respondents' reports of whether or not those recommendations were made do not statistically correlate with add-on measure installation follow-through.

- **Vendor follow-up may be linked to insulation installation.** Respondents whose vendors did not follow up with them after the assessment did not view it as a critical factor in their decisions of whether to pursue add-on measures. However, those who installed insulation were significantly more likely to have had experienced vendor follow up than participants who did not install insulation.



Clarity of information

- **Financing materials and processes confuse some vendors and customers.** Vendors understand and can explain program rebate structures and processes to customers, but some vendors, along with their customers, struggle with the legalistic terminology and complexities involved in applying for financing, especially given the number of finance offerings available. Some vendors suggest that the program simplify language in the financing-related materials and applications.
- **Sources vary in nomenclature.** Vendors often refer to financing options by the organizations that offer the loans, and the Energize Connecticut website sometimes refers to the same loans with different names. These variations may cumulatively add to the participants' and customers' potential confusion.

Executive Summary – Short-Term Persistence and Effective Useful Life

On-site visits to HES-IE multifamily buildings sought to determine the persistence of five portable measures distributed by the program: CFLs, LEDs, faucet aerators, showerheads, and refrigerators. This inquiry resulted in three primary findings (Table 3):

- **Observed measures exceed counts in program data.** Except for LEDs, measures showed *higher* observed counts than what had been recorded in the tracking database. To speculate, this may reflect installations from other programs (e.g., WAP) or independent installations by either landlords or tenants that occurred concurrent with HES-IE services. The study provides little evidence that the *lower* observed counts of LEDs reflect removals by the landlord or tenants to resell the products, as the undercount was distributed across units, and tenants independently confirmed that they had not received those LEDs.
- **On-sites indicate limited measure removal.** Field technicians did not find evidence that tenants had removed a large number of measures, based on verification rates and survey responses. Based on products verified as installed, persistence rates exceeded 90% for all five measures.

- **Removals primarily occur due to breakage.** For those occupants citing removals, the primary reason was burnout or breakage. In the case of showerheads, two of the three were removed because the tenant needed a model appropriate for persons with physical disabilities.

Table 3: On-site Persistence Results

Measures	Sites Visited	Units Visited	Verified Installed	Verified Installation Rate	Number Removed	Measure Persistence Rate[1]
CFLs	12	70	275	107%	18	93%
LEDs	3	17	41	47%	0	100%
Faucet Aerators	12	83	107	184%	4	96%
Showerheads	12	83	53	196%	3	95%
Refrigerators	3	5	3	150%	0	100%

[1] Based on measures verified as received

Participant telephone surveys also measured short-term persistence. In general, the results confirm the on-site visit results (Table 48):

- **Removal occurs due to breakage and dissatisfaction.** Respondents reported removing very few measures. Respondents said that they usually removed measures because they broke or did not work properly.
- **Light bulbs diverged from other measures.** Light bulbs are an anomaly in the on-site study results as the on-site study observed a persistence rate of 93% in HES-IE multifamily units. This stands in contrast to the end-user CATI survey—directed at a different population of end-users; HES respondents reported removing 14% of light bulbs (mainly CFLs), and HES-IE respondents reported removing 11% of light bulbs since participating in the program.[5] Light bulb removals most often resulted from respondent dissatisfaction.
- **Removals occur soon after participation for HES participants but can take up to a year for HES-IE participants.** Most removals for HES respondents happened within four months of program participation, but removals among HES-IE respondents varied from one month (for air sealing) to one year (for duct sealing).

[5] Differences between the on-site HES-IE observed removals and HES-IE self-reported removals may be attributable to 1) the difference in data collection methods where the on-sites allowed for the evaluation team to physically observe units, more nuanced discussion with participants, and confirmations from both end-users and landlords; and 2) the difference in the type of participants: on-site homes were locations where the participant was the landlord in multifamily buildings and the occupants were not necessarily in multifamily buildings and would likely have more sway over the equipment in their homes.

Table 4: End-user Participant Survey Respondents – Verified Measures, Removal Rate, and Timing of Removal

Measure	HES			HES-IE		
	N	% Removed	Average Time Removed[1]	N	% Removed	Average Time Removed[1]
Light bulbs	481	14%	3.4	431	11%	5.2
Water saving measures	247	7%	3.5	330	7%	4.9
Air Sealing	292	2%	3.8	281	1%	1.3
Water pipe wrap	225	<1%	4.0	107	2%	4.0
Duct sealing	81	2%	4.0	27	4%	12.0

Note: Responses are unweighted.
[1] Indicates average number of months from installation to removal.

Executive Summary – Net-to-gross

Using findings from CATI surveys with HES end-user participants, the study estimated a free ridership rate of **0.22** and a spillover rate of **0.02**, resulting in a weighted[6] NTG ratio of **0.80** for the HES program [*(1 – 0.22) + 0.02 = 0.80*].[7, 8]

Free ridership

- **Two-score approach.** Following industry best practices for estimating free ridership from survey responses and using a weighting scheme based on the number of measures and gross savings estimates, the analysis resulted in an HES free ridership score of **0.22** at the 90% confidence level with precision of +/- 3%. Based on sample sizes and confidence intervals, the study suggests updating the PSD for the following: as shown in Table 5, these free ridership rates are for insulation (0.06), water saving measures (0.20), and water pipe wrap (0.28). For more on the estimation method, see Section 5 in the main body of the report and for more discussion of how the evaluation team suggests using the findings see the Net-to-Gross Conclusions and Recommendations.

[6] The free ridership rate is weighted by number of measures (as compared to the population) and by gross annual savings. Spillover is weighted by the average savings values present in the program database associated with the respective measure types (where possible).
[7] The study also estimated net-to-gross ratios of 0.95 for HES-IE and 0.93 for rebate-only programs. The evaluation suggests not using the HES-IE and rebate-only net-to-gross ratios formally because HES-IE programs generally assume a net-to-gross ratio of 1.0, and sample sizes are small among rebate-only respondents.
[8] When compared to similar programs in the Northeast, the HES net-to-gross ratio is somewhat lower, with other programs having ratios greater than 1.0.

- **Importance of Insulation Rebate.** Free ridership for insulation was notably low (0.06) when compared to the other frequently asked-about measures. As a "sensitivity analysis," the study calculated the free ridership rate in absence of insulation measures, arriving at a somewhat higher overall free ridership rate of 0.26 (Table 5).[9] This difference demonstrates the high level of influence that the program has on the installation of insulation and the value of continuing to include insulation as a program measure.

Table 5: HES End-user Participant Survey Respondents – Selected Free Ridership Rates

Measures (n=369 respondents)	n	Average Free Ridership Rate	Confidence Interval[1]	
			Maximum	Minimum
Light bulbs	158	0.55	0.62	0.49
Water pipe wrap	66	0.28	0.37	0.19
Water saving	76	0.20	0.28	0.13
Insulation	140	0.06	0.09	0.03
Total[2]	**601**			
Overall Weighted Average Free Ridership Rates[2]				
With insulation		**0.22**	**0.25**	**0.19**
Without insulation		**0.26**	**0.30**	**0.23**

[1] Figures are at a 90% confidence level.
[2] The total and overall weighted average free ridership rates include all measures presented in Section 5, not just the three shown in this table. The overall average free ridership rate is weighted by number of measures (as compared to the population) and by gross annual savings.

Spillover

- **Eligibility.** Nearly one-fifth of the HES respondents, following their participation in the program, installed or performed an energy-saving measure that did not receive an incentive *and* indicated that their decision to move forward was influenced by the program.
- **Initial results after weighting.** After weighting the percentage of respondents reporting each spillover-eligible measure by the average savings values[10] present in

[9] The non-insulation measures included in the 0.26 estimate are both core services (air sealing, duct sealing, light bulbs, water pipe wrap, and water-saving measures) and other add-on measures besides insulation (AC equipment, clothes washers, heat pumps, hot water heaters, and windows).
[10] Savings values for all fuel types (electric, gas, oil, and propane) were converted into MMBtu. The average MMBtu was used for the weighting.

the program database associated with the measure type (where possible), the analysis resulted in an average *initial* spillover value of 0.06 for the HES program.

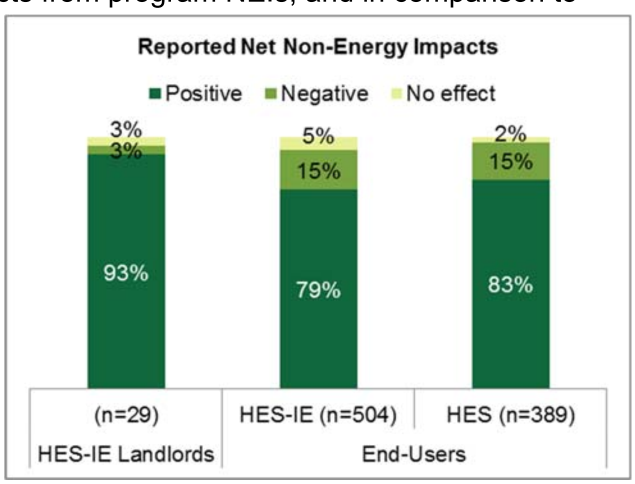
- **Results after adjusting.** To account for the likelihood that light bulbs (the most common spillover-eligible measure reported) had already received upstream rebates, the analysis discounted light bulb savings by half. Then, to account for unknown measure characteristics (quantities and efficiency levels), the algorithm counted one-third of the initial weighted spillover value (0.06), awarding the program some spillover credit where it was due but also making an educated assumption that participants likely install fewer quantities or lower efficiency levels of program-incented measures than what are performed through the program. The adjusted spillover value for the HES program resulted in **0.02** [*0.06 * (1/3)*].

Executive Summary – Non-Energy Impacts

The addition of the value of NEIs to the programs' benefit-cost ratios (BCR; the ratio of monetized value of program benefits to the costs of program administration) has the potential to increase program benefits by millions of dollars. To estimate NEIs from a participant perspective, the study asked participants if the program had a positive, negative, or no effect on various non-energy-related elements in their households or properties. For any elements for which participants observed positive or negative impacts as a result of the program, interview or survey questions asked them to compare the value of that NEI, and then finally all NEIs in aggregate, to the impact of the program on energy savings. From these inputs, the study estimated NEI values using methods consistent with industry best practices.

Net Non-Energy Impacts

Participants experienced positive net impacts from program NEIs, and in comparison to neighboring Northeast programs, they valued program NEIs relatively highly, as well. The vast majorities of end-user and landlord and property manager participants reported positive net impacts. The analysis found overall NEI values of **0.87** for HES end-users, **0.90** for HES-IE end-users, and **0.73** for HES-IE landlords and property manager participants. These values can be considered multipliers that can be translated as a percentage of household energy savings; for example, for every dollar that the average HES household saves on energy costs, the household perceives that they have received an additional 87 cents in NEIs. Adding the end-user NEI values to the programs' Total Resource BCRs could mean



increases in program total resource benefits of **$155.6 million** for HES (45% increase) and **$95.6 million** for HES-IE (64% increase) over the 2016 to 2018 program period.

Specific Impacts

- **Comfort, safety, and property value were positively impacted.** Of all NEIs, landlords and property managers placed the greatest value on the positive impacts on operations and maintenance, tenant comfort, and safety from improved lighting. HES and HES-IE end-user participants placed the greatest value on the positive impacts on comfort, safety from improved lighting, home value or ability to sell the home, and their ability to pay energy bills.
- **Negative NEIs are minimal.** End-users very rarely reported negative NEIs—the few negative impacts that they reported were most often safety issues from perceived dimness of the lighting changes. Landlords and property managers also reported very few negative NEIs, citing only tenant complaints or concerns with safety from lighting or air sealing changes.

NEIs as Participation Drivers

- **Customers may not be tuned into possible NEIs.** Nonparticipants hypothesized that they would experience net positive impacts from NEIs from program participation, but they were less likely to *estimate* that there would be a net positive impact from NEIs than participants were to *observe actual* net positive impacts from program participation.
- **NEIs act as program drivers for landlords.** On average, HES-IE landlord and property managers rated NEIs as somewhat important in their decisions to participate in the program. The interviewees indicated that, to some extent, they had been motivated to participate to improve operations and maintenance, reduce tenants' complaints, and increase tenants' level of comfort. Coupled with the findings on nonparticipants having lower expectations of NEIs than participants actually experience, the collective findings suggest that greater emphasis of NEIs in program marketing materials may be warranted.

Executive Summary – Health and Safety

The study explored health and safety issues through telephone surveys and in-depth interviews with landlords and vendors. Some of the key findings on this topic include the following.

Common Health and Safety Issues Found

- **Participants reported some health and safety issues.** Ten percent of HES end-user participants and 22% of HES-IE end-user participants reported that the program vendors discovered at least one health and safety issue that kept vendors from completing the full assessment.
- **Assessors most often discovered asbestos and vermiculite insulation and knob and tube wiring.** Participants were most likely to fix gas and carbon monoxide leaks and least likely to remedy asbestos and vermiculite insulation.

- **Nonparticipants discovered issues on their own—primarily issues with mold.** NLI nonparticipants (16%) had more often discovered health and safety issues on their own than their HES participant counterparts had discovered during program assessments (10%). Often nonparticipants discovered mold (13%)—unlike program participants, who were more likely to learn that they had asbestos insulation (4% of HES and 8% of HES-IE).
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Barriers to Participation

- **Vendors cited health and safety issues as major barriers to participation.** From the vendor perspective, health and safety issues often prevent projects from moving forward. These issues frequently force technicians to halt the assessment until issues are remediated. Vendors estimated that health and safety issues occur in roughly one-quarter of all jobs (with estimates ranging between 5% and 40%). Participant surveys and interviews did not illustrate the extent to which health and safety issues prevent projects from ultimately taking place (i.e., the problem is never remedied so the home or building never gets needed energy-efficiency measures).
- **Participant and nonparticipation remediation are hindered by cost.** Where health and safety issues are found, remediation costs commonly act as a barrier to having asbestos fixed. While nonparticipants were fairly likely to address issues, they expressed similar reasons as participants for not remedying health and safety issues: the cost and not having gotten around to it.

Executive Summary – Connecticut Contractor Development

The study included interviews with 16 HES vendors who served the program in 2014. The interviews were conducted in combination with those for R46 Financing, R151 Air Sealing, Duct Sealing, and Insulation, and R157 Multifamily Process studies. Questions focused on the qualitative impact of HES on their businesses. The major findings include the following:

- **Vendors say that their businesses' viability largely depends on the existence of HES.** When asked to assess the impact of the hypothetical closing of HES on their businesses,[11] most vendors explained it would have a large negative impact. Some speculated that they would go out of business, and most of the others believed they would have to reduce their staff by 60% to 80%. Only the three vendors who have substantial non-HES work felt that stopping the program would have little impact on their business.
- **The program has led to increased vendor revenue and staffing levels.** Most vendors believed that HES had boosted their revenue and the number of people they had hired, with some vendors saying they had increased their staff levels by 500% to 800%. Vendors who saw post-HES increases in revenue and/or staffing attributed almost all of it to HES.

[11] The interviewers stressed this was completely hypothetical.

- **Vendors believe the program has helped expand their energy efficiency business and the general market for energy efficiency services.** When asked to use a zero-to-ten scale to rate the impact of HES on the amount of work for their business specifically and the energy efficiency services industry generally, every vendor rated both indicators at six or higher. The average impact on their own business was 9.5, and for the industry in general it was 8.4.
- **Program-related business varies as portions of vendors' revenue.** Vendors serving HES fall into two types: Those who rely almost exclusively on HES for their work (75% to 100%) and those for whom HES supplements (50% or less) their other work. Five of the 12 vendors answering this question said 100% of their work comes from HES, but three said less than 10% of their work did.
- **Vendors are skeptical that HES will continue to grow.** Vendors were less certain that the HES-related growth can be sustained for either their business or the industry, ranking both with an average of about 7.0 on the same 10-point scale. Vendors generally felt the work load would continue at current levels.[12]

Executive Summary – Connecticut Clean Energy Communities

The eighth study module, also known as Study R152, involved an assessment of the role played by the Connecticut Clean Energy Communities (CEC) program in boosting participation in HES and uptake of deeper savings measures. This assessment entailed interviews with utility program staff members and leaders of energy-related community groups. The study also examined rates of HES and other CEEF program participation and deeper-measure uptake through statistical analyses of program data available on the Energize Connecticut dashboard and of the HES program tracking databases for 2014.

- **Successful CEC communities have a core group of motivated community members to spearhead community engagement.** Formalizing the group as a town committee or task force assists in continuity and sustained activity, avoiding the disintegration of activity that can occur as one or two motivated individuals leave the group.
- **Leveraging existing community events improves program outreach**. The importance of this finding is best summed by an interview quotation: "People come to get their kids' faces painted and leave with information on insulation and lighting efficiency."
- **Strong utility staff promote program success.** Community leaders repeatedly spoke about the assistance, responsiveness, and resourcefulness of utility staff in ensuring their communities' success.
- **Community members suggested that additional structure or guidance could be added to the CEC program to aid in community engagement.** They appreciated program flexibility and creativity but also felt that some additional structure may be helpful.

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[12] It should be noted that when benchmarked against another nation-wide program, Connecticut HES vendors' expectations were relatively high. Section **Error! Reference source not found.** details this comparison and its caveats.

- **Statistical analyses failed to find a consistent relationship between CEC program outreach, HES participation, and deeper-measure uptake.** Simple statistical approaches (Chi-Squared tests and analysis of variance) suggested that utility staff outreach is associated with increased CEC points earned by the town.[13] However, more sophisticated regression analyses that controlled for income, concentration of renters, and a "green" culture failed to find consistent relationships between CEC program outreach, the CEC points earned in 2014, and uptake of deeper measures.

Executive Summary – Document Review

The document review assessed the materials and resources that Energize Connecticut and the utilities provide in support of the HES and HES-IE programs, and whether those materials and resources are effective, clear, engaging, and accessible to potential program participants and vendors. The document review also assessed the relationship between the evaluation's recommendations and the review findings to help identify successes and possible areas of improvement.

The analysis has indicated that the participation and financing materials and vendor documentation tools offered are generally clear and effective resources for customers and vendors to utilize. Some participants responding to the CATI survey recommended increasing advertising and the quality of information provided about the program. HES short-term respondents were significantly more satisfied than long-term respondents with the quality of program information, and both HES and HES-IE short-term respondents were significantly more satisfied with the rebate and incentive information when compared with long-term respondents, possibly signaling program improvements or superior recall due to more recent participation.[14]

- **Participation materials.** Program materials contain a substantial amount of information about the assessment process that should be easy to understand from the customer perspective. The Energize Connecticut website and the HES Comprehensive Home Energy Report are relatively straightforward in their descriptions of program processes.

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[13] Towns that earn 100 points are eligible to apply for grants of $5,000 to $15,000 to fund energy-efficiency initiatives. http://www.energizect.com/your-town/solutions-list/clean-energy-communities

[14] Note that this evaluation included an experimental approach to test whether traditional delayed process evaluation results might differ from responses obtained close to the time of actual program participation. "Short-term" refers to participants who were surveyed closer to the time of participation (six to nine months post-participation), and "long-term" survey respondents refer to participants who were surveyed at a later time (after nine months post-participation). See Section 1.1 for additional details.

- **Financing materials.** The program produces a number of materials and resources to support customers as they learn about the financing options that are available to them. The Energize Connecticut website and its online financing tool as well as the Print-on-Demand (POD) Booklet (used by vendors when speaking with customers during the kitchen table wrap-up after the assessment) provide a good deal of background information for customers, but customers may find it valuable to speak with a specialist to clarify the process and specific steps needed (and the order in which steps should be taken). Vendors are provided with a chart of financing options, and the Implementation Manual instructs vendors to refer customers to the Energize Connecticut website to learn more about financing options. At times, the Energize Connecticut website and the lending organizations use different names for the various financing options (e.g. a reference to "micro loans" on the CHIF website does not appear on the Energize Connecticut website).
- **Vendor documentation tools.** The program produces a number of materials and resources to support vendors as they work to educate customers about the assessment and program offerings. The Implementation Manual is a useful resource for vendors in guiding customers through the program. The manual instructs vendors to assist customers in filling out rebate forms and to discuss the rebate and incentive options with them. It also provides detailed instructions for vendors about how to discuss the results of the energy assessment with customers and offers example language to use when explaining the results. Additionally, vendors are provided with a financing chart as well as a short description of rebate and incentive offerings to help them better explain these opportunities to customers.
- **Marketing materials.** The program provides many different marketing materials to reach potential HES customers. An analysis of these materials indicates that there are several marketing channels used, including traditional means (e.g., newspapers, bill inserts, brochures, letters, television, and phone outreach), as well non-traditional means, such as paid advertisements on Pandora Radio and Facebook, and Google pay-per-click advertisements. The marketing materials provided appear to be clear and easy to understand.

Executive Summary – Database Review

The Companies provided participation data for their HES, HES-IE, and rebate programs for participation that occurred between July 2013 and April 2015. The evaluators undertook numerous steps to clean, merge, and assess the data. Most of the findings and recommendations gained through this task have largely been incorporated into the R33 Database Improvement Task.[15] Additional findings identified during on-site visits or as part of the estimation of deeper measure update and home energy assessment wait times have

[15] *Observations & Recommendations from CT Residential Program Database Interviews*.http://www.energizect.com/sites/default/files/Observations_Recommendations_CT%20Resi%20Pgm%20Database%20Interviews%20%28R33%29%20-%20Final%20Report%2C%201.26.16.pdf.

been incorporated into the On-site Persistence (Section 4.1) and Process Evaluation (Section 2) findings, respectively.

Conclusions and Recommendations

The study points to numerous conclusions and recommendations, leading with overarching conclusions and recommendations and then discussing those related to particular study modules and their related objectives.

Overarching Conclusion and Recommendations

Data collection and management.[16] The on-site persistence visits identified apparent errors in the program tracking database. As these were discovered after the R33 study was conducted, that study did not address them. The data for several sites appeared to incorrectly indicate the presence or absence of program measures. For example, refrigerator units that occupants reported as having been installed through the program were not listed in the tracking data. Similarly, refrigerator units were not found in apartments listed as receiving refrigerators through the tracking system. Listing more detail on-measure installations (such as brand/SKU for lighting and make/model/serial number for equipment) would allow for a more rigorous verification for future undertakings. Additionally, the vendor/database analysis could not be completed for all populations because some of the databases neglected to include vendor names.

- **Recommendation 1:** The evaluation recommends that the Companies work closely with the program implementers and vendors to ensure that program data are entered into the tracking database correctly. Explore ways to enhance quality assurance/quality control procedures to verify the accuracy of data entry.[17]
- **Recommendation 2:** It is critical for tracking databases to be developed/organized to account for evaluation aims as well as program implementation. Specifically, if CEEF-funded and non-CEEF-funded measures are installed in program units, it is important to impact evaluations that the total number and type of measures installed through any funded source be listed. The study recommends encouraging vendors and community action agencies to follow the Companies' preferred standardized protocols for listing all measures installed in units regardless of the funding source in order to improve the accuracy of impact evaluations. Lacking such tracking, it is unlikely that future evaluations will be able to improve upon the efforts here at tracking measure persistence rates and helping participants differentiate among measures they received from the Companies and from other sources. Additionally, vendor names should be tracked in program data for all participants and programs.

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[16] The database review yielded additional insights but those have been addressed in the R33 Database Management Study. http://www.energizect.com/sites/default/files/Observations_Recommendations_CT%20Resi%20Pgm%20Database%20Interviews%20%28R33%29%20-%20Final%20Report%2C%201.26.16.pdf

[17] It should be noted that the Companies have been recognized by the U.S. Department of Energy (DOE) as already having a robust quality assurance/quality control model. *Source*: Richard Oswald, UI; February 16, 2016; draft report comments, "R4 HES/HES-IE Process Evaluation and R31 Real Time research."

Program Processes

Participant satisfaction. Satisfaction is high among end-user and landlord and property manager participants. End-users were highly satisfied with the program overall, in particular with core services and add-on measures. HES-IE landlord and property manager participants were also highly satisfied with add-on measures, but one of their suggestions—despite their high level of satisfaction with their vendors—was for the program to improve the quality of core services because they had received complaints from tenants about safety concerns stemming from the perception that the efficient lighting was too dim and quality concerns when it came to the air sealing (see Recommendation 24 below). Some persistence issues among end-users were also linked to product quality.

- **Recommendation 3:** Given this information, and the information discussed in the short-term persistence and EUL findings, it may be beneficial to reevaluate the quality of the actual materials that vendors are installing. See Recommendation 16 below for specific recommendations on lighting.

Program awareness. Nonparticipants reported moderately high awareness of the programs. Word of mouth and utility outreach are effective marketing approaches as they were the channels through which participants became informed about the programs.

- **Recommendation 4:** Participants themselves suggested that the program increase its advertising.[18] In an effort to leverage vendors' desires to increase their own business revenues, the program may wish to engage HES and HES-IE nonparticipants through co-op marketing with vendors.

Program drivers. Participants' desire to save energy and energy costs drove them to participate; additionally, they have observed energy reductions since the program improvements were made. In contrast, nonparticipant end-users do not participate because they have not made energy efficiency a priority, do not see a need, or find the cost prohibitive.

- **Recommendation 5:** Any new advertising should emphasize the value of the program. In particular, continue emphasizing the proven energy and energy cost savings that the program improvements will create for participants. The messaging could focus on addressing customers' skepticism that there is not a need to make improvements or on their "haven't gotten around to it" attitudes by emphasizing bill and energy savings of acting now rather than putting off improvements. It would also be beneficial if the messaging stressed how little the assessments themselves cost, especially when compared to the value of the services provided.

[18] It should be noted that The Companies fully expended their marketing budgets in 2015. Refining or targeting this marketing may improve the cost-effectiveness of the program's marketing efforts.

Communication. HES-IE landlords and property managers found that the entire participation process took longer than they expected. They also expressed frustration with program communications, including unreturned phone calls and emails to a program contact, discontinuity in communication, and a lack of communication with the contractor about important details of the work being done.

- **Recommendation 6:** The property managers and landlords had insightful suggestions for improving communications that the study considers worthwhile. They suggested creating a single contact for all program-related communications, communicating more clearly about timelines upfront, carrying out more direct communication as opposed to relying on third-party contractors, and clearly conveying what to expect from the technicians. The study suggests that the program address the timing issue by focusing on increasing the speed of rebate processing and communication response time with landlords. This recommendation appears to support and complement the Companies' current efforts to streamline the application and review process.

Decision Making and Financing

Program offering information. The HES program uses a variety of methods to educate customers about program offerings. Utility marketing through bill inserts or through the program website are relatively common sources of awareness of rebates and incentives. The HES program also relies heavily on vendors to promote and explain these offerings to eligible participants. However, some end-users expressed disappointment with the quality of rebate and incentive information, and one of their common suggestions was to improve the program's quality of information. However, as noted above, short-term survey respondents were significantly more likely to be highly satisfied with the quality of the rebate and incentive information provided when compared with long-term respondents, possibly signaling program improvements or superior recall due to more recent participation. The following recommendations are still encouraged for consideration to ensure that all customers and vendors are provided with the information that they need to make informed decisions.

- **Recommendation 7:** Vendors are currently provided with resources to help them understand and explain the program to customers, including language to use when discussing the program offerings. Providing vendors with additional or more detailed talking points and materials to encourage customers to consider add-on improvements may help overcome some of the challenges some end-users have expressed with the quality of information.
- **Recommendation 8:** The program does a good job of providing both print and online materials to support customers. (The website is well-designed and informative, for example.) However, clarifying or offering additional details about program offerings in customer-facing materials and marketing efforts may also help to address customer concerns over information quality.

Program incentive and rebate levels. The program offerings have been popular with customers, especially the insulation allowance that covers 50% of installed cost. Program participants as well as nonparticipants often cite not having enough funds to cover the down payment to make improvements as a key reason for not moving forward with the work.

- **Recommendation 9:** Continue offering substantial rebates and financing for insulation because free ridership is low and participants respond positively to them.
- **Recommendation 10:** If cost-effective, consider increases to incentives for other measures, given the success proven with 50% insulation allowance.

Financing materials and processes. Financing materials and processes confuse some vendors and customers. Vendors understand and can explain program rebate structures and processes to customers, but some vendors, along with their customers, struggle with the legalistic terminology and complexities involved in applying for financing. Some vendors suggest that the program simplify the language in the financing-related materials and applications.

- **Recommendation 11:** Provide an “everyday language” version of the loan application to accompany “legalese” documents through working with loan providers. Given that a greater percentage of Massachusetts households rated their loan application for the Massachusetts HEAT Loan program (the state has one overarching residential loan program) as easy to fill out (97% versus 43%), the EEB, Companies, and funding agencies may want to review the Massachusetts’ application materials for potential ideas on how to improve applications in Connecticut.[19]
- **Recommendation 12:** Continue expanding and updating existing materials that provide financing information, such as the vendor-focused Implementation Manual, or the customer-focused POD Booklet used during the wrap-up after the assessment. These documents already include some information and language about financing options that vendors can use, but it may be useful to provide more details or to clarify the messaging. In particular, the Implementation Manual could encourage vendors to explain the options in detail to better ensure that that the customer understands the options and how best to take advantage of them. Additionally, the POD Booklet could provide a clearer explanation of the relationship between the table of offerings and the Energy Conservation Loan Program described on the following page.
- **Recommendation 13:** Provide vendors with talking points and materials on sales methods to use when customers are initially opposed to the idea of applying for a program loan.

Financing sources vary in nomenclature. Vendors often refer to financing options by the organizations offering the loans, but the Energize Connecticut website and the websites of

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[19] The Massachusetts HEAT Loan program is structured similarly to the Connecticut Energy Conservation loan. It is important to note that the Massachusetts program administrators are directly involved in the development of the loan program; in Connecticut the program administrator’s role in the development of the loan materials is very limited. For more details on the Massachusetts HEAT Loan program visit http://www.masssave.com/~/media/Files/Residential/Information-and-Edu-Docs/HEAT-Loan-Eligibility-Options-Generic.ashx.

individual financing organizations sometimes refer to the same loans with different names. HES participants already voice confusion and some skepticism about financing, and these variations in nomenclature may add to participants' and customers' potential confusion.

- **Recommendation 14:** Provide guidance to vendors, website developers, and funding agencies about preferred language to use when referring to financing. Make certain that all websites and materials—vendor, program, and funding agency—use consistent nomenclature. Keep financing option name changes to a minimum, but when changes are necessary update all program materials and websites simultaneous with rolling out the name change.[20] Make certain the vendors and program staff use consistence language, both in informal discussions (this will make the terminology second nature) as well as in written materials, such as the vendor-targeted Implementation Manual.

Short-Term Persistence and Effective Useful Life

On-site visits verified high short-term persistence rates on portable measures. Based on the on-site assessment, the study did not identify persistence issues related to removal of the portable measures verified for multifamily participants of the HES-IE program.[21] Because persistence rates were so high, it was not possible to estimate EUL for the portable measures examined in the on-site persistence study.

- **Recommendation 15:** The study finds no evidence to justify downwardly adjusting persistence rates or measure lives for CFLs, LEDs, faucet aerators, showerheads, or refrigerators in HES-IE multifamily units. The Companies should continue to use current assumptions as listed in the 2015 PSD in Appendix 4 at this time.[22]

LEDs persistence exceeds that for CFLs. The analysis estimated a higher persistence rate for LEDs than CFLs. This may be due to the fact that HES-IE on-site participants anecdotally expressed higher satisfaction with LEDs than with CFLs in terms of both aesthetics and performance.

- **Recommendation 16:** Given the increased marginal savings achieved by LEDs over CFLs, the greater tendency for participants to keep program LEDs installed compared to CFLs, and the longer measure life for LEDs, the program should continue its efforts in the 2016 to 2018 program cycle to shift resources from CFLs to LEDs, eventually making LEDs the default standard socket lighting measure for the program.[23] Note that, although the specification is technology neutral, no CFLs

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[20] The Companies provide vendors with updates regarding new or changing financing options during quarterly meetings as well as during periodic email communications.
[21] The 2010 NEEP study by KEMA performed verification on a small sample of multifamily buildings, which included a mix of commercial and residential multifamily spaces. This may have conflated the concern around CFL persistence.
[22] United Illuminating Company and Connecticut Light and Power. 2014. *Connecticut Program Savings Document: 10th Edition for 2015 Program Year.* Document dated November 5, 2014.
[23] The program increased its courtesy LED offering in 2016 from four lamps to six bulbs, and plans to offer more in the future. An unlimited number of LEDs are offered through the HES program at a subsidized price in conjunction with customer co-pay.

currently on the market will qualify for the ENERGY STAR label as of January 2, 2017 based on the recent Lamp 2.0 specification released by ENERGY STAR. Thus, it is likely that the switchover to LEDs will happen somewhat rapidly.[24]

Net-to-Gross

Net-to-gross (NTG) ratios. Using findings from CATI surveys with HES end-user participants, the study estimated a free ridership rate of **0.22** and a spillover rate of **0.02**, resulting in a NTG ratio of **0.80** for the HES program. When compared to similar programs in the Northeast, the HES NTG ratio is somewhat lower, with other programs having ratios greater than 1.0. The study also estimated NTG ratios of 0.95 for HES-IE, and 0.93 for rebate-only programs. It is worth noting that Connecticut factors NTG ratios into its "net realization rates" in the PSD; at this time, the 2015 PSD lists only free ridership and spillover for individual measures and does not list overall program free ridership or spillover or overall NTG ratios.[25]

- **Recommendation 17:** The evaluation team suggests that the Companies consider the findings of this study when revising overall program free ridership, spillover, and realization rates in the PSD *for the HES Program*. For some HES measures, the confidence intervals are small enough and sample sizes large enough to serve as measure-specific free ridership values that the evaluation team suggests using for the PSD: insulation (0.06), water saving measures (0.20), and water pipe wrap (0.28). Two measures with adequate sample size require special attention. First, while the HES light bulb confidence interval was small and the sample size was large, the evaluation team suggests using the upstream lighting NTG ratios of 51% for CFLs and 82% for LEDs (as reported in the R86 Lighting NTG and LED Market Assessment study).[26] Had households obtained these bulbs on their own, many would have obtained upstream bulbs. Second, as reviewers have pointed out, the type of air sealing customers perform on their own most likely would not be blower-door guided; therefore, a free ridership rate of zero should be assumed for this HES measure. All other HES measures with larger confidence intervals or too small sample sizes should not be used to update the PSD, but they do provide information that could inform future revisions and studies. The evaluation team suggests not using the overall HES-IE and rebate-only NTG ratios formally because HES-IE programs generally assume a NTG ratio of 1.0, and sample sizes are small among rebate-only respondents to adjust PDF assumptions.

In January 2016, the HES-IE program began offering unlimited courtesy LED replacements in high-use sockets as identified in the 2016 Connecticut Program Savings Documentation. Unlimited courtesy CFLs are to be installed in low-use sockets due to cost-effectiveness limitations.

[24] See https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd for more details.

[25] The United Illuminating Company and Connecticut Light & Power. 2014. *Connecticut Program Savings Document: 10th Edition for 2015 Program Year.* Specifically, Appendix 3: Realization Rates.

[26] NMR Group, Cadmus Group, and DNV GL. 2015. R86: Connecticut Residential LED Market Assessment and Lighting Net-to-Gross Overall Report. Delivered to the Energy Efficiency Board, May 2015. http://www.energizect.com/your-town/ct-residential-led-lighting-market-assessment-and-lighting-ntg-r86final

Insulation free ridership. Free ridership for insulation was notably low (0.06) when compared to the other frequently asked-about measures. As a "sensitivity analysis," the study calculated the free ridership rate in absence of insulation measures, arriving at a somewhat higher overall free ridership rate of 0.26. This difference demonstrates the high level of influence that the program has on the installation of insulation and the value of continuing to include insulation as a program measure.

- **Recommendation 18:** Considering the low free ridership rate and also the enthusiasm among customers for the insulation rebate opportunity that vendors observe, the program will benefit from continuing to offer its generous incentive for this cost-effective measure.
- **Recommendation 19:** Given the relatively low free ridership rates and higher adoption rates for insulation coupled with the claim by participants that would adopt more measures with deeper incentives, free ridership rates for some measures may actually decrease if the Companies increase incentives. That is, free ridership may be higher at lower incentive amounts, but higher incentive amounts really move people to adopt a measure that they otherwise would not have adopted. This would have the net effect of increasing the cost-effectiveness of higher incentives. As also stated in Recommendation 10**,** the Companies should consider increases to incentives or financing allowances for other measures where cost-effective.

Non-Energy Impacts

Overall NEI values. Participants experienced positive net impacts—household and other effects beyond energy savings—from the program. These positive NEIs far outweighed any negative NEIs. The vast majorities of end-user and landlord and property manager participants reported positive net impacts. The analysis found overall NEI values of **0.87** for HES end-users, **0.90** for HES-IE end-users, and **0.73** for HES-IE landlords and property manager participants. Adding the NEIs derived from this study to current estimates of total program benefits relative to costs increases BCRs for all fuels and Companies, as described earlier and in the main body of this report.

- **Recommendation 20:** The evaluation suggests that the program consider structuring future evaluation efforts to estimate how NEI values such as these could be added to program BCRs to increase program total resource benefits. Because the current study was not structured to provide fuel or measure-specific NEIs, the evaluation does not recommend revising the current BCRs but the results of this study should be taken into consideration during future revisions.

Perceptions of NEIs. HES-IE landlords and property manager participants perceived potential NEIs as a driver for their participation. Both they and end-user participants reported that comfort, property value, and safety were positively impacted, in particular. Vendors also agreed that participants would be likely to experience comfort and safety as a result of their participation and regularly mention these benefits as selling points during the assessment. Nonparticipants hypothesized that they would experience net positive impacts from NEIs from program participation, but they were less likely to *estimate* that there would be a net positive impact from NEIs than participants were to *observe actual* net positive impacts from program participation. That is, participants and nonparticipants diverge in terms of the impacts they expect from the program—which thereby affects their internal calculations of return on investments relative to the program and potentially their participation decision.

- **Recommendation 21:** While the program should continue prioritizing energy savings as a central marketing message, the divergence between nonparticipants' lower expectations for NEIs and participants' actual experiences with NEIs suggests that increasing the emphasis on NEIs in program marketing materials may also be warranted. Leveraging the benefits of NEIs will help to convey the value of the program to customers. Specifically, NEI messaging should focus on the positive impacts on comfort, property value, and safety, perhaps through end-user testimonials. This may help bring nonparticipants' expectations of NEIs to values closer to those of participants, which could potentially increase participation rates from the same expenditures on outreach, thus reducing program cost per customer sign-up and increasing program-induced energy savings.

Health and Safety

Improved health and safety in terms of fewer illnesses, better air quality, and reduced fire risk are among the program NEIs named by participants and vendors. Yet, the study made clear that other health and safety concerns actually prevent the provision of services to some single-family and small-multifamily (two-to-four unit) homes and can delay services to multifamily buildings. Additionally, some landlords voiced concerns about tenant safety related to perceived dimness of efficient lighting.

Health and safety as barriers to participation. Vendors perceive health and safety issues as major barriers to participation, estimating that these issues impact close to one-fourth of all jobs. These issues frequently force technicians to halt the assessment until issues are remediated.

- **Recommendation 22:** This is a challenging barrier to address. Continuing to provide clear and effective health and safety-oriented messaging and support to end-users, landlords, and vendors may help to address these issues over the long term. Additionally, the program should continue its efforts in improving the tracking of the prevalence of these barriers and working with health and safety partners throughout the state to refer homes with identified health and safety barriers to these organizations for assistance.

Remediation costs. Both participants and nonparticipants said that the costs associated with remediation of health and safety issues are a hindrance. For participants, these costs (often associated with asbestos insulation) act as barriers to having the full assessment take place.

- **Recommendation 23:** For both HES and HES-IE end-user participants and landlords/property managers, provide more information on the financing options—including some external to the program—that cover at least part of the costs of remediating health and safety issues. Continue encouraging financing partners to improve options for financing or assisting with remediation.
- **Recommendation 24:** When replacing light bulbs, make certain that the lumens duplicate or exceed the lumens of the bulb being replaced, unless doing so creates additional safety concerns (e.g., the wattage of the new bulb would be too great to use safely in the fixture). This applies to the interior and exterior of all single-family homes and multifamily buildings as well as common areas in multifamily buildings.

Connecticut Contractor Development

Indicators of effects. Vendors recognize the value that the program has carried for expanding their energy efficiency business and the general development of contractors that provide energy efficiency services in the state. Not only has the program led to increased vendor revenue and staffing levels, but many vendors' businesses' viability largely depends on the existence of HES; in fact, some vendors rely almost exclusively on HES for their revenue.

- **Recommendation 25:** Given these positive indicators that the program has had a positive effect on the development of contractors in the state from the perspective of vendors, the EEB may wish to conduct a larger study to quantify the extent of program market effects. A study along these lines would generally involve interviews or surveys with product distributors/suppliers and participating and nonparticipating installation contractors.

Program structure. Vendors do not always agree with changes in rebates and measures offered. For example, a few vendor interviewees mentioned their disagreement with the decision to shift some rebates upstream rather than continue supporting the rebates directly via HES.

- **Recommendation 26:** Given vendors' reliance on the program and the program's implicit reliance on vendors to have an impact on the market (and support program participation), it is pivotal to get vendor input before deciding to make structural program changes to foster a sustainable relationship between the program and its vendors. Additionally, any changes that are made should ideally be accompanied by clear communications to the vendors regarding the reasons for the changes and the mechanics or implications of the changes.

Connecticut Clean Energy Communities

Structure and guidance for Clean Energy Communities. Clean energy community leaders appreciated the flexibility and creativity afforded to them for hosting community events and reaching out to their constituencies. They did not that formalized town committees or paid positions help provide sustained activity and continuity for individual communities.

- **Recommendation 27:** While the Companies cannot mandate the way that towns organize their own activities, they could suggest that towns formalize CEC positions within the town municipal structure so that if a key person leaves, someone new steps into that role.

Evaluation Data Collection

Short-term data collection. Regarding surveys, comparisons of short-term and long-term respondents only occasionally differed from each other statistically. Additionally, the short-term survey was fielded at least six to nine months post-participation. Yet, the differences observed suggest that short-term respondents are more satisfied with core services and program information on savings and incentives, are more likely to say they have or will use program rebates and incentives, and exhibit lower levels of free ridership.

- **Recommendation 28:** Weighing all of this information, the study recommends that the EEB and Companies strongly consider fielding **one more** short-term survey using an instrument very similar to R31 within three to six months of program participation. This survey should provide enough information to allow for a definitive recommendation of whether a continuous short-term survey effort is justified for Connecticut HES, HES-IE, and downstream residential rebate programs.

Language barriers. While the majority of HES-IE participants—and the eligible population—speak English, a sizable (but unknown) portion primarily speak other languages, with Spanish being the most common. The available study budget did not support conducting telephone surveys or on-site interviews in Spanish, thus limiting who could respond to the telephone survey and leading one landlord to decline participation in the on-site visits. In another building, the landlord acted as interpreter so the study could include Spanish-speaking participants.

- **Recommendation 29:** For future studies that reach out to HES-IE participants, the EEB and EEB Evaluation Consultants should attempt whenever possible to ensure that the studies be planned and adequately funded to ensure inclusion of non-English-speaking (primarily Spanish-speaking) customers. Providing adequate resources would allow future evaluations to hire trained bilingual technicians and interviewers, which would improve the exploration and characterization of the substantial non-English-speaking portion of the eligible population.[27]

[27] Note that the program already provides many customer-facing materials in both Spanish and English, such as print, newspaper, and radio advertisements, program brochures, and rebate forms. Resources for vendors are also provided in both Spanish and English, such as the POD Booklet to be used by vendors at kitchen table "wrap ups".

1 Section 1 Background and Methodology

Home Energy Solutions (HES) and Home Energy Solutions-Income Eligible (HES-IE) are the two flagship programs in the Connecticut Energy Efficiency Fund (CEEF) residential program portfolio. According to the 2014 annual report, these two programs collectively served 51,947 residences in Connecticut in 2014.[28] They ranked first and second in terms of residential program budgets for 2015 (35% for HES and 32% for HES-IE) and first and fourth in terms of expected 2015 residential savings in total annual MMBtus (31% for HES and 19% for HES-IE).[29,30] The idea driving both programs is that the home energy assessment leads homeowners, renters, landlords, and property managers to adopt additional energy-saving measures, some of which are eligible for rebates or program-supported financing options.[31] In short, the programs ideally serve as an entry point for capturing deeper savings.

Given the importance of the two programs and their offerings in the residential portfolio, the Connecticut Energy Efficiency Board (EEB) tasked the research area contractor NMR Group, Inc., and its partner The Cadmus Group with conducting a series of related studies of the HES and HES-IE programs. The four main studies are as follows:

- **R4 Process Evaluation of the HES and HES-IE programs** examined program processes, health and safety concerns, customer decision making regarding participation and deeper-measure uptake, measure persistence, NTG ratio estimation, and non-energy impacts for participants from July 2013 through December 2014.
- **R31 Short-term Data Collection** addressed many of the same issues as R4 but for HES and HES-IE participants as well as outside program rebate users from January to April 2015.
- **R46 Financing Study**, leveraging resources from the R4 and R31 studies, assessed awareness of, reactions to, and use of the various zero percent or low-interest financing options available to Connecticut ratepayers through the CEEF (some of which require HES or HES-IE participation).
- **R152 Clean Energy Communities (CEC) Assessment,** again leveraging resources from the R4 study, explored the degree to which this community outreach

[28] Connecticut Energy Efficiency Board. 2015. *Energy Efficiency Board 2014 Programs and Operations Report*. Available at http://www.energizect.com/sites/default/files/Final%20ALR%202014%20Pages.2.26.15.pdf.
[29] Connecticut Light & Power, The United Illuminating Company, The Yankee Gas Services Company, Connecticut Natural Gas Corporation, and Southern Connecticut Gas. 2014. *2015 Annual Update of the 2013-2015 Electric and Natural Gas Conservation and Load Management Plan.* See Table A-1 for budget and B-3 for expected savings. Note that the 2016 to 2018 plan is now available, but the study cites the 2015 update given the retrospective nature of the evaluation.
[30] Retail Products had the second highest expected savings (23%) and Behavior the third highest (22%).
[31] The findings section of this report provides more information about distinctions between HES and HES-IE. Additional information is available on the Energize Connecticut website at http://www.energizect.com/your-home/solutions-list?ptype=1.

program influenced participation in HES and deeper-measure uptake, while also providing some insights into the characteristics of successful CEC communities.

The four studies explored topics through eight individual topic modules, including conducting telephone surveys with 1,372 program participants and non-participants; in-depth interviews with 30 HES-IE landlords/property managers, 23 HES vendors, two Clean Energy Communities program staff members, and four energy-efficiency community group leaders; and 13 visits to HES-IE multifamily buildings (86 units in total).

Table 6 on the next page outlines the modules and their objectives and research questions, while Table 7 maps each module to the research tasks designed to answer these questions. The remainder of this section describes the methods used across the four studies.

Table 6: Research Modules, Objectives, and Questions

Module	Major Objectives / Research Questions
Module 1: Program Processes, Experience	Program awareness, experience, satisfaction; clarity of program materials; wait time for receiving services
Module 2: Health and Safety	Degree to which health and safety concerns limit services; types of concerns found; mitigation of health and safety concerns
Module 3: Decision making and Financing (Study R46)	Awareness/use of rebates and financing; role of rebates and financing in decision to install measures; ease of applying for rebates and financing; vendor experience promoting rebates and financing
Module 4: Non-energy Impacts	Whether participants experienced non-energy impacts (NEIs); which NEIs they experienced; value placed on impacts; impacts expected by nonparticipants; vendor discussion of impacts
Module 5: Net-to-Gross Ratios	Likelihood of purchasing measures without program incentives; additional purchases made because of program experience
Module 6: Persistence and Effective Useful Life	On-site verification of persistence of portable measures in HES-IE multifamily buildings; self-reported persistence of additional measures (via telephone); early check-in for EUL where appropriate
Module 7: Connecticut Contractor Development	Degree to which program has increased revenue and staff for vendors' companies and for energy efficiency service providers more generally; degree of reliance on HES for work
Module 8: Clean Energy Communities (Study R152)	Degree to which activities performed through the CEC Program has induced participation in HES and uptake of deeper measures

Table 7: Mapping of Study Modules and Tasks

	Task 1: Participant and Nonparticipant Surveys	Task 2: HES-IE Multifamily Landlord Interviews	Task 3: On-site Visits	Task 4: Program database review	Task 5: Program document review	Task 6: Bench-marking	Task 7: Vendor Interviews	Task 8: CEC in-depth interviews and database analysis
Sample Size	*R4 participants = 833* *R31 participants = 299* *R4 nonparticipants = 240*	*30*	*Sites = 13* *Units = 86*	*N/A*	*N/A*	*N/A*	*23*	*6*
Module 1: Process and Experience	X	X	X	X	X	X		
Module 2: Health & Safety	X	X					X	
Module 3: Decision making, Financing	X	X			X	X	X	
Module 4: Non-energy Impacts	X	X			X	X	X	
Module 5: Net-to-Gross	X	X				X		
Module 6: Persistence & EUL	X	X	X			X		
Module 7: Connecticut Contractor Development						X	X	
Module 8: CEC Impact on HES								X

1.1 Task 1 – End-User Surveys – Methodology

Surveys with end-user participants and nonparticipants explored program processes, health and safety, decision making and financing, non-energy impacts, net-to-gross, and persistence.

1.1.1 End-user Participant Surveys

The end-user participant surveys were conducted in two waves: 1) surveys with HES, HES-IE, and rebate-only end-users fielded in September 2015 as part of the R31 study, and 2) surveys with HES and HES-IE end-users fielded in September and October 2015 as part of the R4 study.

1.1.1.1 Short-term Data Collection (R31)

As described earlier, this survey effort incorporated the R31 study as the first of two survey waves. The R31 study piloted the effectiveness of performing participant surveys addressing program processes and decision making in a timeframe closer to their dates of participation. R31 surveyed not only HES and HES-IE, but also end-user rebates obtained outside of HES.

The R31 study was originally referred to as "real-time" data collection with the intention to speak with participants within a few months of participation. Due to challenges aggregating participant contact data, coordinating the survey instrument with R4 objectives, finishing CATI survey programming, and ironing out sampling issues, the surveys took place six to nine months after participation. As a result, the analysis refers to these respondents—responding within nine months after participation—as short-term respondents instead of real-time respondents.[32]

The short-term surveys asked the same question modules as the long-term (R4) participant surveys with the exceptions of excluding health and safety, persistence, and spillover question modules and including an additional feedback question module.

1.1.1.2 Sampling

Table 8 presents the end-user participant survey sampling errors and other sampling details. The overall sampling error for the combined R4 and R31 participant surveys was 3.0%, with the sampling error per individual strata ranging from 5.6% to 10.4%. The analysis weighted the results so that they better represented the program population in terms of participation period (i.e., survey timing – R4 vs. R31), program (HES vs. HES-IE vs. rebate-only), and type of measures installed (core service only vs. non-insulation add-ons vs. insulation). For some topic areas, the nature of the analysis necessitated the use of an alternative weighting scheme (e.g., net-to-gross was weighted to program savings and

[32] Not all R31 respondents were ultimately considered short-term respondents because some sample sizes were too small and the CATI team needed to re-enter the field to obtain additional completes. The analysis considers respondents that completed surveys more than nine months after participating to be long-term respondents even if they were contacted as part of the R31 survey effort.

measure types) or no weighting scheme (e.g., persistence and NEIs). Appendix A.1.1 presents the R4 and R31 survey weights.

Table 8: End-user Participant Survey Sample Design – Population, Sample Size, and Sampling Error by Stratum, Study, and Participation Period

Stratum / Group	Study	Participation Period	Population Size	Sample Size	Sampling Error
HES – Core Only	R4	July 2013 to December 2014	15,979	194	5.9%
HES – Insulation			4,022	123	7.3%
HES – Other Add-ons			1,420	116	7.3%
HES-IE Core Only[1]			3,958	209	5.6%
HES-IE Add-ons[1]			4,296	191	5.8%
Core Only	R31	January to April 2015	5,500	119	7.5%
Insulation			1,167	60	10.4%
Add-ons			646	60	10.2%
Rebate Only[2]			815	60	10.3%
Total	**Both**	**July 2013 to April 2015**	**37,803**	**1,132**	**3.0%**
HES	R4	July 2013 to December 2014	21,421	433	4.6%
HES-IE[1]			8,254	400	4.0%
R4 Total	**R4**	**July 2013 to December 2014**	**29,675**	**833**	**3.5%**
R31 Total	**R31**	**January to April 2015**	**8,128**	**299**	**5.4%**

[1] Excludes participants that were not occupants/end-users: Eversource Subprogram 3 (Multifamily) and Subprogram 4 (Neighborhood Canvassing) contacts and UI contacts that appeared to be from commercial/property management entities.
[2] Represents respondents that received rebates outside of the HES umbrella

1.1.1.3 Response Rates and Completions by Company

The R31 participant survey was fielded from September 4 to September 22, 2015, and then was briefly re-opened for fielding from November 11 to November 15, 2015, in order to ensure adequate representation by program and Company. A total of 299 CEEF program participants were surveyed. The response rate was 17%, as determined using a calculator developed by the American Association of Public Opinion Research (AAPOR;[33] Table 9). Excluding numbers at which surveyors only left messages on answering machines or voicemail increases the rate to 19%. Both calculations exclude those screened from the survey and unusable phone numbers. Appendix A.1.1 provides additional details on why some eligible participants did not answer the survey.

The R4 participant survey was fielded from September 21 to October 17, 2015. A total of 832 participants in the HES and HES-IE programs were surveyed. The AAPOR calculation

[33] American Association for Public Opinion Research (2015) "Response Rate Calculator" Excel File available at www.aapor.org/AAPORKentico/Education-Resources/For-Researchers/Poll-Survey-FAQ/Response-Rates-An-Overview.aspx. Accessed December 31, 2015.

estimates a response rate of 10% including numbers at which surveyors left messages and 15% excluding message only numbers. It is worth noting that the response rate was higher for the R31 survey, for which the respondents generally had participated more recently than for R4; higher response rates reduce non-response bias, offering one argument in favor of fielding short-term surveys. However, here the higher response rate for R31 has more to do with the "active"[34] sample remaining at the end of calling. Specifically, in order to reach quotas for R4, the survey firm had to release additional sample towards the end of calling. They began calling the newly released sample and left many answering machine messages but reached all quotas before contacting most of the answering machine numbers again. The R31 survey did not have to release more sample in order to reach quotas, therefore avoiding this situation.

Table 9: End-User Participant Surveys – Response Rates[1]

(Base = all phone numbers dialed at least once)

Response Rate	R4		R31	
	w/ Answering Machine	w/o Answering Machine	w/ Answering Machine	w/o Answering Machine
All Numbers Dialed	11,669	7,848	2,498	2,180
I=Complete Interviews	832	832	299	299
P=Partial Interviews	41	41	44	44
R=Refusal and break off	1,568	1,568	869	869
NC=Not Contacted	810	810	105	105
O=Other	120	120	40	40
e=Estimated Proportion of Unknowns that are eligible[2]	0.762	0.762	0.823	0.823
UH=Unknown Households	7,248	3,427	850	532
Response Rate[3]	10%	15%	17%	19%

[1] Response rate calculated using the AAPOR Outcome Rate Calculator
[2] (I+R+NC+O)/[(I+R+NC)+(W+NE)]
[3] (I+P)/((I+P) + (R+NC+O) + e(UH+UO))

[34] Survey contacts are "active" when they have been added to the call list but their final disposition (whether they completed the survey and, if not, why) is still unknown.

Table 10 presents the distributions of the records that the Companies provided, the usable records within those, and the survey sample across Company and program. Appendix A.1.1 provides greater details on the development of the sample frame, demonstrating how the removal of duplicate, commercial, and incomplete contacts reduced the sample frame size (i.e., number of usable records). In summary, the most common reason for removals was the lack of usable contact information. Variations from the percentage of usable records versus percentage of completed surveys reflect the degree of customer cooperation by survey group, but also, to some extent, may be due to the availability of mailing information.[35]

Table 10: Participant End-User Surveys – Comparison of Participant Population versus Sample by Company and Study

Stratum / Group	Eversource					UI				
	Population			Sample		Population			Sample	
	Number of Original Projects	% of Original Projects	% of Usable Records[1]	Number of Completed Surveys	% of Completed Surveys	Number of Original Projects	% of Original Projects	% of Usable Records[1]	Number of Completed Surveys	% of Completed Surveys
R4 Study										
HES	20,443	62%	54%	377	45%	3,892	12%	10%	56	7%
HES-IE	5,931	18%	25%	345	41%	2,885	9%	12%	56	7%
R31 Study[2]										
HES	4946	38%	64%	114	38%	-	-	-	-	-
HES-IE	5163	39%	26%	125	42%	-	-	-	-	-
Rebate-only[3]	3077	23%	10%	60	20%	-	-	-	-	-

[1] Refers to records with unique contacts and adequate contact information.
[2] UI opted not to provide sample for R31 as they were in the midst of performing follow-up with participants.
[3] Refers to projects that received rebates outside of the HES umbrella, according to program records.

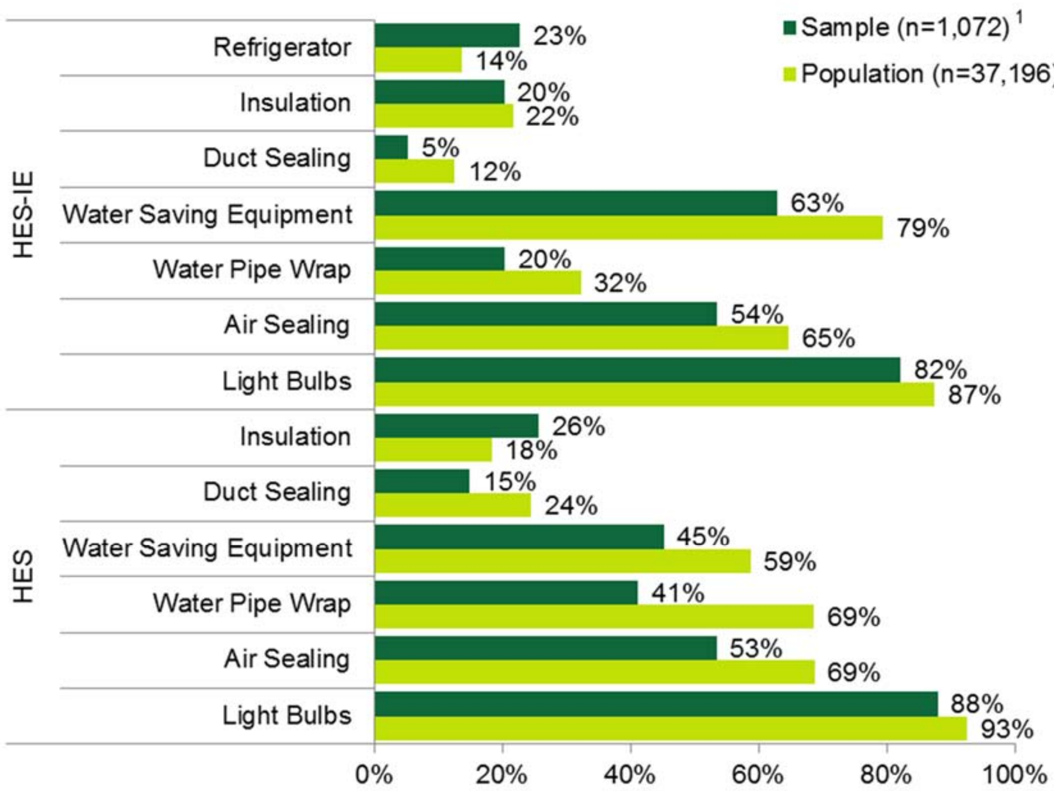
[35] Surveys were preceded by letters notifying participants that they would be contacted to complete the survey. Mailings were conducted in waves, and the contacts were dialed shortly after they would have received their letters. Some data provided by the Companies did not include the ZIP codes; as a result, the CATI team reserved those contacts for dialing after they made efforts to contact the participants who had received letters.

1.1.1.4 Respondent Characteristics

Appendix B.1 presents respondents' housing and demographic characteristics. Figure 1 compares the program measures that respondents verified during the survey with the most common measures in the program population. With the exception of HES insulation and HES-IE refrigerators, it appears that the survey under-sampled the other measure types—but much of this may be a result of inaccurate self-verification on the part of respondents. Appendix A.1.1 compares the verified sample measures with the full list of population measures.

Figure 1: End-user Participant Survey – Verified Sample Measures Compared to Population Measures

(Percentage of contacts)



Note: Figure includes only the most common program measures.
[1] Percentages are based on the number of contacts in each program type: the end-user population consisted of 26,762 HES participants and 10,434 HES-IE participants; the sample consisted of 547 HES participants and 525 HES-IE participants.

1.1.2 End-user Nonparticipant Survey

End-user nonparticipant surveys were conducted with Company customers who had not participated in HES or HES-IE. The overall sampling error is 5.4%, assuming a 50% break in responses. The sampling error for HES-eligible homes was 7.0% and for HES-IE-eligible homes was 8.4%.

Table 11: End-user Nonparticipant Survey Sample Design – Population, Sample Size, and Sampling Error by Stratum

Stratum[1]	Population Size[2]	Sample Size	Sampling Error
Non-low-income	1,749,141	140	7.0%
Low-income	925,564	100	8.4%
Total	**2,676,705**	**240**	**5.4%**

[1] Income eligibility was based on self-reported household size and household income compared with HUD's estimated 80% area-median income across Connecticut communities (which are slightly less generous in considering people low-income if incomes are less than $70,000 as compared to HES-IE program eligibility criteria). The analysis considered respondents that would not or could not provide household size and/or income information as NLI.
[2] Population estimates are approximate and are derived from the Census Bureau's Data Ferret. The estimates are based on all households in Connecticut and are adjusted for income and household size. Adjusting for municipal utilities would have virtually no effect on sampling error due to the large sample size.

1.1.2.1 Response Rates and Completions by Company

The R4 nonparticipant survey was initially fielded from September 24 to October 21, 2015, and then, due to performance issues with the first CATI firm, the EEB requested switching firms. The second firm fielded the survey from November 23 to December 13, 2015. A total of 240 nonparticipant customers were surveyed. The AAPOR calculator estimated a response rate of 1% with answering machines and 3% without them (Table 12).[36] As with the end-user participant surveys, the methods exclude from the calculation those who were screened from the survey and unusable phone numbers. Appendix A.1.2 provides additional details on why some eligible participants did not answer the survey.

Table 12: Nonparticipant Survey - Response Rate[1]

(Base = all phone numbers dialed at least once)

Response Rate	Nonparticipant	
	w/ Answering Machine	w/o Answering Machine
All Numbers Dialed	20,765	8,635
I=Complete Interviews	240	240
P=Partial Interviews	3	3
R=Refusal and break off	1,877	1,877
NC=Not Contacted	2,555	2,555
O=Other	88	88
e=Estimated Proportion of Unknowns that are eligible[2]	0.919	0.919
UH=Unknown Households	15,604	3,474
Response Rate[3]	1%	3%

[1] Response rate calculated using the "AAPOR Outcome Rate Calculator"
[2] (I+R+NC+O)/[(I+R+NC)+(W+NE)]
[3] (I+P)/((I+P) + (R+NC+O) + e(UH+UO))

[36] The response rate with answering machines included for the two firms were 3% for the initial firm and 1% for the second firm. The second firm had to release more sample to finish the survey, but did so before re-contacting numbers originally sent to answering machines.

With the goal of representing the customer distribution between the two Companies, two-thirds of the sample frame consisted of Eversource customers, and the remaining one-third consisted of UI customers. Completed surveys were slightly skewed toward Eversource; 73% of respondents were Eversource customers and 27% were UI customers (Table 13), reflecting differential cooperation rates.[37] The analysis properly weighted the results by income and dwelling type (multifamily versus single-family) as compared to the population in Connecticut.[38]

Table 13: Comparison of Nonparticipant Records Provided Versus Sample by Company

Utility	Number of Records Provided	Usable Records[1]	% of Usable Records	Number of Completed Surveys	% of Completed Surveys
Eversource	3,400	3,118	67%	176	73%
UI	1,600	1,504	33%	64	27%
Total	**5,000**	**4,622**		**240**	

[1] Refers to records with unique contacts and adequate contact information. Eight percent of the 5,000 customer contacts that the Companies provided were unusable mostly because they were commercial contacts (additional details in Appendix A.1.2).

1.2 Task 2 – HES-IE Landlord and Property Manager Interviews – Methodology

The HES-IE landlord and property manager interviews asked interviewees about program processes, decision making and financing, short-term persistence, free ridership, spillover, non-energy impacts, and health and safety. This task resulted in 30 interviews completed with landlords and property managers, including 29 telephone interviews and one in-person interview.[39]

1.2.1 HES-IE Landlord and Property Manager Interviews – Project Characteristics

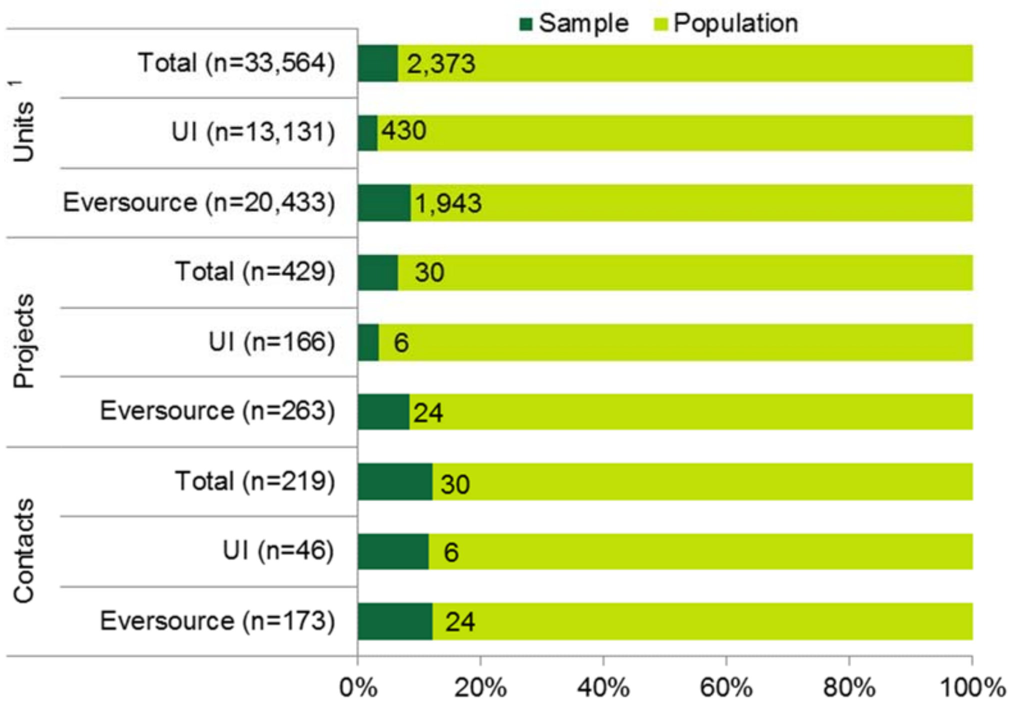
Interviewers asked each landlord and property manager about one of their projects served by the program (referred to as their "key project") between July 2013 and April 2015. If the landlord or property manager was involved with more than one participating project,

[37] Survey management monitored the distribution of completed surveys between the two Companies, but also needed to prioritize the focus on achieving income-base quotas.
[38] Population data came from U.S. Census Bureau/Data Ferret. 2009-2013 American Community Survey. www.dataferret.census.gov December 2015.
[39] The evaluation included an interview with one property manager in person because when the study attempted to recruit him for the R157 Multifamily Initiative Process evaluation HES focus group, the contact reported participating in the program a great deal. A scheduling issue prevented the property manager from attending the actual focus group, but it was determined that it would be important to interview this contact to learn more. During the interview, it was gleaned that the interviewee had participated in HES-*IE,* not HES, and as a result, the study uses the responses from that interview (which did not follow the same question structure, yet did touch on the same themes) in the analysis of these HES-IE landlord in-depth interviews.

interview questions focused on the project with the largest amount of gross electric savings as reported in the program database.

Of the 30 projects, 24 were served by Eversource and six were served by UI. The 30 projects included 2,373 housing units, representing 7% of the projects and estimated number of units in the HES-IE participant multifamily population[40] between July 2013 and April 2015,[41] in total. The key projects ranged in size from five to 360 units, with an average of 79 units per project and a midpoint of 41 units per project (Table 14).[42,43] Figure 2 compares the sample in terms of the number of units, projects, and unique landlord and property manager contacts to the HES-IE multifamily participant population.

Figure 2: HES-IE Landlord and Property Manager Interviews – Sample Comparison to HES-IE Multifamily Participant Population



[1] In the absence of unit-level data in UI's participation database, the study estimated the total number of units in the UI multifamily population by multiplying the mean units per projects among the key projects (79.10) by the number of UI projects in the participation database (166).

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[40] The base population (429 HES-IE projects) excludes projects where the occupant was the point of entry into the program. In-depth interview sampling targeted projects only if the landlord or property manager was the point of entry.
[41] UI did not provide participation data for 2015.
[42] Table 114 in Appendix B.2.1 includes a more detailed breakdown of the key projects' sizes.
[43] Because UI's participation database does not capture the number of housing units in projects, the study estimated the number of units among UI projects by multiplying the mean units per projects among the key projects (79.10) by the number of UI projects in the participation database (166) to estimate the number of participating units.

Table 14: HES-IE Landlord and Property Manager Interviews – Number of Units in Sample and Multifamily Population

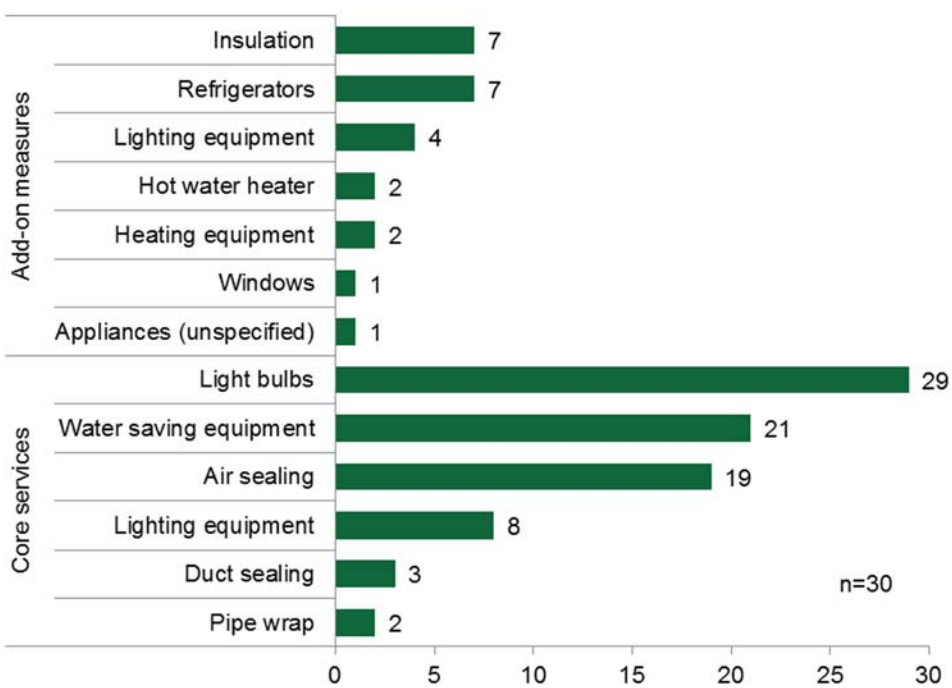
HES-IE Units per Project		Eversource	UI[1]	Total[1]
Multifamily Participant Population (n=429 projects)	Average	78	-	-
	Median	51	-	-
Interview Sample (n=30 projects)	Average	81	72	79
	Median	46	26	41

[1] UI's participation database does not capture the number of housing units in its projects; as such, the table does not report the average or median number of units among the full population.

Figure 3 presents the program measure types installed at the 30 key projects. The key projects were most likely to have received incentives for refrigerators (7 projects) and insulation (7); for core services, they most often received light bulbs (29), water-saving equipment (21), and air sealing (19).

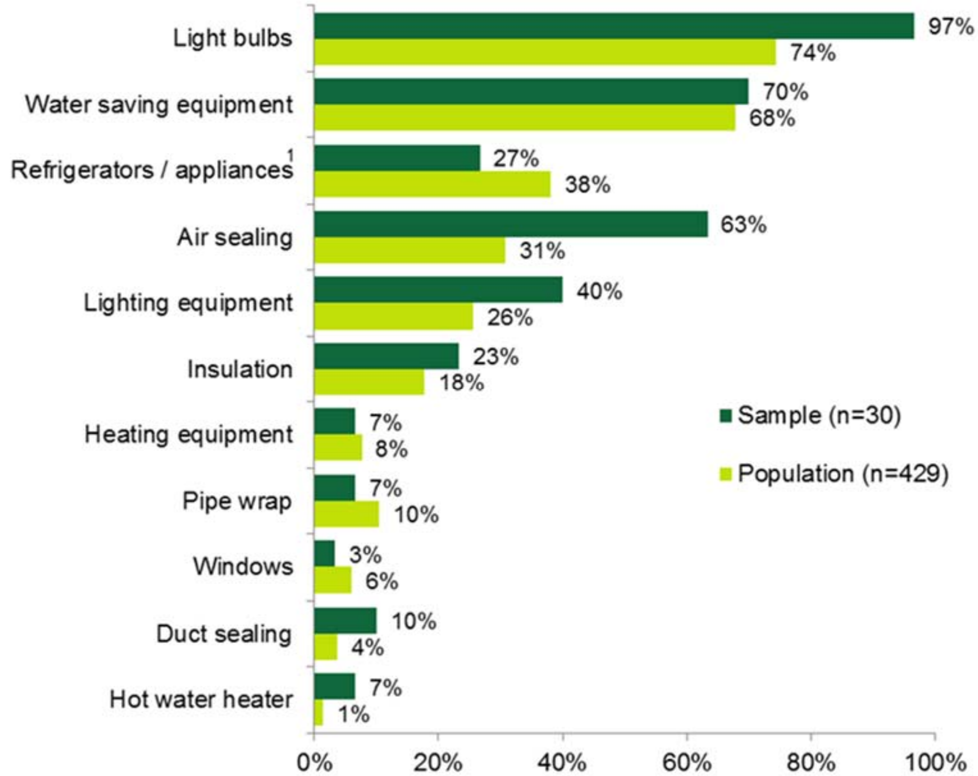
Figure 3: HES-IE Landlord and Property Manager Interviews – Program Measures at Key Project

(Count of projects)



As illustrated in Figure 4, when compared to the HES-IE multifamily project population, the HES-IE landlord and property manager key project sample over-represented some measures (in particular, light bulbs and other lighting equipment and air sealing). For example, nearly all of the key projects had light bulbs installed (29 of 30) compared to one-quarter of the full HES-IE multifamily project population,[44] and more than three-fifths of the sample (63%) had air sealing conducted, but slightly less than one-third of the multifamily population (31%) had it conducted. The report includes firmographics about the interviewees' companies in Appendix B.2.2.

Figure 4: HES-IE Landlord and Property Manager Interviews – Sample Comparison to HES-IE Participant Population Measures



Note: The chart excludes a few measure types where none of the key projects installed those measures (e.g., central air conditioners and heat pumps); each represented 15 projects or fewer in the HES-IE multifamily population.

[1] Program tracking data did not specify the type of appliance for 72% of the 163 projects with either refrigerators or other appliances.

1.3 TASK 3 – ON-SITE PERSISTENCE VISITS – METHODOLOGY

The study involved performing on-site verification to estimate short-term persistence of portable measures (e.g., light bulbs as opposed to insulation) installed in multifamily residences (five or more units) under the HES-IE program. Even though both HES and HES-IE serve multifamily buildings, the persistence study focuses on HES-IE.[45] Measures

[44] This difference may reflect the study's sampling approach. The study leveraged the HES-IE landlord and property manager in-depth interviews to recruit sites for the R4 on-site short-term persistence research where the sampling focused first on projects that had measures relevant to that study (light bulbs, water-saving equipment, and refrigerators). As a result, projects with quantifiable measures, such as light bulbs, were given preference when it came to interviewing.

[45] The EEB Evaluation Committee considered expanding the study to include HES but ultimately voted against that option.

examined include compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs), direct hot water measures (showerheads and faucet aerators), and refrigerators. The research approach determined persistence through a simple visual inspection during the same visit. The effort also sought to understand why participants may have removed products.[46]

The study defined persistence as the percentage of program measures that remained installed at the time of the survey or on-site visit (discussed below). Specifically, this study focused on research around key program measures and their short-term persistence (i.e., measures that remain installed within a few years of installation).[47, 48] Appendix A.1.3 includes additional details on the on-site methods and background.

1.3.1 On-site Persistence Visits Approach

To estimate short-term persistence for portable measures, the study included on-site visits in 86 multifamily units across 12 buildings. The visits were at sites that had participated in the HES-IE program in the period from 2013 to 2015. Through landlord and property manager in-depth interviews (described in Section 1.2), the approach involved the recruitment of landlords and property managers willing to permit on-site verification in one of their buildings or complexes that had participated in the HES-IE program. The study provided participating landlords and property managers with a $100 gift card for gaining approval and coordination in conducting the on-site assessment. Additionally, the study provided $25 gift cards to occupants who responded to a short interview regarding measure persistence at the time of the site visit.

1.3.1.1 Verification Methodology

Site verification of measure persistence can identify at least two different types of problems. If the number of measures identified on site is fewer than the number of measures claimed by the program, two questions arise: 1) Is the amount recorded in the program database an error due to implementation or database problems? 2) Were the measures removed subsequent to installation? For the latter question, the research is dependent on self-reporting by tenants, which can be subject to errors of recall and of normative bias.[49] The

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[46] While on site, technicians marked program CFL and LED lamps, writing the date of the site visit at the bulb's base using a heat-resistant fine-point marker. Technicians marked a total of 307 lamps out of 333 lamps (the others could not be accessed due to fixture location or type) identified, including both program and non-program lamps. This activity will allow for future persistence studies that the EEB may wish to perform to track the long-term persistence of lamps identified during this first visit.

[47] Short-term persistence is different from EUL. EUL is the length of time one can expect a program measure to continue working after it has been installed. While evaluators typically define EUL to be the point at which 50% of the measures can be expected to fail (the median life), this evaluation will serve as an early check-in for this important lifetime savings parameter. The study assumes that the EEB will fund future EUL check-ins for HES- and HES-IE-supported measures in order to update EUL over time.

[48] Note that a prior commercial and industrial area study that included some multifamily units in the analysis found that the 10-year persistence rate for compact fluorescent lamps (CFLs) was 33% and the two-year persistence rate was 73%. This unexpected finding served as one of the drivers of the current study. See KEMA. *C&I Lighting Measure Life and Persistence Project: Final Report*. Prepared for NEEP 2010. Available online: http://issuu.com/neepenergy/docs/neep_ci_persistence_report-final/1?e=12509042/8424638.

[49] In other words, there can be a response bias where the participant is providing responses they perceive are socially desirable, rather than accurate.

study was designed to estimate the percentage of program measures that were verified to be installed at the time of the assessment compared to the number as recorded in program tracking databases as well as the number recalled as installed by the tenants. There are, thus, two baseline denominators against which verified installed measures have been calculated and reported.

During the on-site visits, technicians collected data detailing whether the portable measures were still installed. For this study, while technicians used program tracking data listing the expected measure quantities, they did not identify and verify program equipment from lists of measure brands and model numbers.[50] However, they were able, with a high degree of confidence, to identify program equipment based on 1) the expectation that identical measures were installed throughout the units in a building,[51] and 2) corroboration from occupants. For measures not found, technicians asked occupants whether a measure had been removed and, if so, when and why it had been removed. Where possible, technicians spoke with the occupants of the housing units, as the occupants were in the best position to explain why a measure no longer persisted. However, if the occupants were not aware of the installation (because they moved in after its removal, for example), the technicians documented in-unit measure verification and asked the landlord, property manager, or building manager if they knew the date and reason for the measure removal and were able to communicate and interpret the questions.[52]

The verified installation rate calculation uses the following formula:

$$Verified\ Installation\ Rate = \frac{Verified\ Received\ Quantity\ - Removed\ Quantities}{Tracking\ Database\ Quantity}$$

Given the substantial differences in quantities found on site and verified to have been installed by the landlord or tenant compared to the tracking database, the analysis has not used these values in the calculation of persistence rates. Rather, this study uses the number of measures that were verified received as the basis for calculating persistence:

$$Persistence\ Rate = \frac{Verified\ Received\ Quantity\ - Removed\ Quantities}{Verified\ Received\ Quantity}$$

1.3.1.2 Sample Design

The study developed the proposed sample size and calculated results according to procedures for cluster sampling that account for variability both across and within projects in an effort to make data collection as cost-effective as possible. This design also reflects the fact that, each year, the programs provide services to relatively few multifamily buildings but thousands of units within them. Projects were the primary sampling unit and housing

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[50] The program tracking databases did not provide information such as make/model, so the study needed to assume that a measure type that looked like other confirmed program measures in the building were likely program models.
[51] The study examined only the residential units—not the common areas—of these buildings.
[52] At one site, the majority of tenants did not speak English. For this site, the field technicians completed as many of the surveys as possible with the landlord translating. The study approach only counted these surveys as completed if the tenants clearly demonstrated that they understood the questions.

units within projects were selected at random. The study recruited landlords and property managers through in-depth interviews with HES-IE landlords and property managers who were the point of entry into the program. In order to achieve the desired number of completed visits, the evaluators also recruited landlords through direct calls, with the landlords selected based on known information about the number of units served in order to achieve study objectives.[53] A summary of recruitment and scheduled on-sites by utility is provided in Table 15.

Table 15: HES-IE Recruitment and Scheduled On-Sites

(Count of projects)

Recruitment and scheduling process		Eversource	UI	Total
HES-IE participants with data and contact information		140	46	**186**
Completed IDIs		24	6	**30**
IDIs recruited	Recruited for on-sites	13	5[1]	**18**
	Scheduled for on-sites	8	1	**9**
Non-IDI recruited	Recruited for on-sites	6	-	**6**
	Scheduled for on-sites	4	-	**4**
Total on-sites		12[2]	1	**13**

[1] Unit-level data for all five UI sites expressing interest in the site visit were requested, though only one landlord actually followed through and agreed to schedule an on-site visit.
[2] For one site, data issues prevented complete on-site verification against tracked values; given this and sufficient sample to meet targets, this site was omitted from the analysis.

[53] No additional UI landlords were recruited via this method due to a lack of interest. Attempts to contact each of the 46 UI landlords were made at least six and up to nine times. Additionally, while six UI landlords completed interviews (20% of completions), only five expressed interest in the on-sites, and only one followed through with agreement to schedule the actual visit. Thus, while the study strived to maintain the original 75% Eversource/ 25% UI split of landlords with contact information in the original database, the completed on-site visits included only one UI site (8%).

The evaluation aimed to achieve at least ±10% sampling error at the 90% confidence level, sampling ten projects and a minimum of seven units per project. The assumption informing the sample design was that landlords and property managers have relatively limited influence on tenant behaviors with respect to program measures. Thus, the average measure persistence rates would be relatively homogeneous across the population of buildings, with the variability in persistence rates arising across units. As shown in Table 16, the evaluation completed 86 site visits across 12 building sites, more than the sampling target of 70 total units across 10 buildings.

Table 16: HES-IE Short-Term Persistence On-Site Visits – Actual Sample Compared to Targeted Sample

Sample	Number of Sites	Average Housing Units per Site	Total Number of Sites
Targeted			
Statewide	10	7	70
Actual			
Eversource	11	7.1	78
UI	1	8.0	8
Total	**12[1]**	**7.2**	**86**

[1] Number differs from previous table due to omission of one Eversource site as noted above.

1.4 Task 4 – Database Management, Cleaning, and Review – Methodology

The Companies provided participation data for their HES, HES-IE, and rebate programs for participation that occurred between July 2013 and April 2015. The evaluators undertook numerous steps to clean, merge, and assess the data to 1) determine how and if it could serve R4, R31, R46, and R152 and other studies' research efforts;[54] 2) estimate deeper-measure uptake by vendor and home energy assessment wait times; 3) prepare sample frames for end-user, landlord/property manager, and vendor surveys and interviews; and 4) evaluate the organization, completeness, consistency, and usability of the program participation database. The findings and recommendations gained through this task have largely been incorporated into the R33 Database Improvement Task.[55] Additional findings identified during on-site visits or as part of the estimation of deeper-measure update and home energy assessment wait times have been incorporated into the On-site Persistence (Section 4.1) and Process Evaluation (Section 2) findings, respectively.

[54] The additional studies included R113, R151, and R157.
[55] NMR Group, Inc. Forthcoming. *Observations & Recommendations from CT Residential Program Database Interviews*. http://www.energizect.com/sites/default/files/Observations_Recommendations_CT%20Resi%20Pgm%20Database%20Interviews%20%28R33%29%20-%20Final%20Report%2C%201.26.16.pdf.

1.5 Task 5 – Program Document Review – Methodology

Energize Connecticut and the utilities provided marketing materials, program resources, and other documentation used to support the HES and HES-IE programs. The document review assessed these materials and resources, as well as the program website, to understand whether they are effective, clear, consistent, engaging, and accessible to potential program participants and vendors. The document review also assessed whether any existing materials or resources currently support the evaluation's recommendations.

1.6 Task 6 – Benchmarking – Methodology

Where possible, the study compared its findings to those of other evaluations of similar programs in the Northeast United States that were published in the last three to four years. If recent examples in the Northeast were unavailable or too limited, the study benchmarked the HES/HES-IE programs against older studies or studies of programs outside of the Northeast. Comparisons were made only to other evaluation findings and not planning documents, deemed values, or screening tools, as these other values could represent considerations and assumptions other than those typical of evaluation methods.

1.7 Task 7 – Vendor Interviews – Methodology

Given the relatively small pool of vendors and overlapping research objectives, in-depth interviews with program vendors were coordinated with the R151 Air Sealing, Duct Sealing, and Insulation Practices Report and the R157 Multifamily Process Evaluation; the former is currently under public review.[56] This coordinated approach endeavored to maximize efficient outreach to program stakeholders and minimize respondent fatigue. The interviews touched on four of the study modules. They were conducted either in person (during an R151 on-site visit) or via the telephone with one or two vendor employees who had knowledge of the topic areas—although, in order to limit respondent fatigue, only some vendors were asked to respond to the entire battery of questions. The study prioritized decision making and financing questions, a reflection of the importance of R46 Financing Evaluation objectives and additional budget allocated to address them. Table 17 summarizes the number of vendors queried and the research questions addressed in each module.

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[56] NMR Group, Inc. 2015. *Connecticut HES Air Sealing, Duct Sealing, and Insulation Practices Report (R151).* Draft posted for public review December 2015. http://www.energizect.com/sites/default/files/CT%20HES%20Air%20Sealing%2C%20Duct%20Sealing%2C%20and%20Insulation%20Practices%20%28R151%29_review%20draft_12.23.15.docx.; NMR Group. 2015. *Multi-family Initiative Process Evaluation (R157).* http://www.energizect.com/sites/default/files/R157%20-%20Multifamily%20Initiative%20Process%20Evaluation%2C%20Final%20Report%2C%203.8.16.pdf

Table 17: Vendor Interview Modules, Sample Sizes, and Research Questions

Module	Number of Vendors Responding	Research Questions
Module 2: Health and Safety	10[1]	Degree to which health and safety concerns act as a barrier to measure installation
Module 3: Decision and Financing	23	Experiences discussing and promoting rebates and financing with participants
Module 4: Non-energy Impacts	17	If/how they discuss NEIs with participants; own thoughts on which NEIs participants are most likely to experience
Module 7: Connecticut Contractor Development	17	Degree to which the program has and will boost their business staffing and revenue and the energy services market in Connecticut

[1] Also addressed in R151 Air Sealing, Duct Sealing, and Insulation Practices Report

1.8 Add-on Studies (R46 and R152) – Methodology

1.8.1 R46 Financing Evaluation

As mentioned earlier, the R46 Financing Evaluation leveraged the participant, nonparticipant, landlord, and vendor survey and interview efforts to delve more deeply into program actors' awareness, knowledge, opinions, and use/promotion of various financing options available to residents of Connecticut. Table 18 summarizes which tasks addressed decision-making and financing and the major questions covered in the inquiry.[57]

Table 18: R46 Financing Tasks, Sample Sizes, and Research Questions

Research Task	Number of Respondents	Research Questions
Task 1: End-user HES Participant and Nonparticipant Surveys (includes R31 Surveys)	547 Participants; 240 Nonparticipants	Awareness and use of financing,[1] drivers of and barriers to using financing, ease of applying, importance and influence of financing, and satisfaction with financing programs
Task 2: Landlord and Property Manager Participant Interviews	30	Awareness and use of financing,[1] drivers of and barriers to using financing, ease of applying
Task 5: Document Review	N/A	Clarity, accuracy, and consistency of financing brochures, applications
Task 7: HES Vendor Interviews	23	Experiences discussing, promoting rebates and financing with participants

[57] Although the study offered to compare self-reported and actual participation in financing programs for the telephone survey respondents and perform a financing database review, the Companies declined this offer.

[1] If interviewees reported receiving financing, interviews and surveys asked for clarification on the type and name of the entity providing the financing.

1.8.2 R152 Connecticut Clean Energy Communities Assessment

Task R152 was a two-part sub-project to assess the Connecticut CEC program in boosting participation in HES and uptake of deeper savings measures. The first task included in-depth interviews with utility staff associated with CEC as well as leaders of energy-related community groups from towns that were identified as successful under the CEC program. These interviews were designed to develop a qualitative understanding of the replicable factors that are associated with successful community engagement with the CEC program as well as recommendations for program improvement, all with a focus on how program success may influence HES participation and deeper-measure uptake. The second task involved statistical analyses of CEC program data, as reported on the Energize Connecticut dashboard, as well as HES program tracking databases for 2014 in order to assess the effectiveness of CEC program activity in boosting participation in HES and deeper-measure uptake.

The in-depth telephone interviews were completed in the fall of 2015, with separate interview guides developed for the utility staff and for the community leaders (both of which are reproduced in full in Appendix C). Both interview guides contained questions aimed at identifying the characteristics and actions of successful towns in the CEC program and ties between those characteristics and actions, and participation in HES and deeper-measure uptake. The utility staff interviews had two additional objectives: 1) to identify contact information for communities deemed to be successful examples of engagement with the CEC program and 2) to determine what data sources, if any, were available that would be useful in augmenting the publicly available Energize Connecticut dashboard data in developing a quantitative assessment. The utility staff interviews were initially planned as two separate interviews, one for Eversource and one for UI. However, for scheduling reasons and adherence to the project timeline, the program managers and evaluators decided to hold a combined interview. The study completed in-depth interviews with four community leaders who had been identified by program staff as representing “successful” CEC case studies.

The statistical analysis portion of the project drew from the following four sources:

1. Publicly available data from the Energize Connecticut Dashboard on rates of program participation and community points earned as a result of participation and measure uptake in various residential, municipal, and small business programs[58]
2. HES program tracking databases for 2014
3. Event description, estimated attendance numbers, dates, and location of CEC outreach activities for 2012 through mid-2015, as supplied by the Companies

[58] Towns that earn 100 points are eligible to apply for grants of $5,000 to $15,000 to fund energy-efficiency initiatives. http://www.energizect.com/your-town/solutions-list/clean-energy-communities

4. Income data from the American Community Survey and rental data from the 2010 Census of Population and Housing

These data, normalized to town population, were analyzed using chi-squared tests, analysis of variance, and ordinary least squares regression to determine if any association between utility program outreach and CEC outcomes could be found as well as to assess possible relationships between utility program outreach and HES participation rates and deeper-measure uptake in the communities.

2 Section 2 Program Process Findings

The R4 research project used surveys with HES and HES-IE participating and nonparticipating end-use customers as well as in-depth interviews with HES-IE landlords and property managers to evaluate the HES and HES-IE program processes. Survey and interview topics addressed program processes, including program awareness, participation drivers and barriers, marketing and outreach, participant satisfaction, and participant experiences with and attitudes toward energy savings, as well as gathered suggestions for program improvement. Process results showed the following key themes:

- Satisfaction is high among end-users and landlords and property managers. Ratings were quite high for the actual measures installed. Landlords and property managers expressed some dissatisfaction with program timing and communication, and end-users gave their lowest satisfaction ratings to the quality of rebate and incentive information that they received.
- Program awareness among nonparticipants is moderately high.
- Word of mouth and utility outreach have been effective marketing approaches.
- A desire to save energy and save on energy costs drives participation.
- Nonparticipants do not or cannot prioritize energy efficiency because they have not made energy efficiency a priority, do not see a need, or find the cost prohibitive.
- Many participants observe energy savings that are roughly in line with expectations.
- Participants offered a variety of suggestions.
    - End-user participants suggested improving program work quality and information, expanding offerings, and increasing advertising.
    - HES-IE landlords and property managers suggested that the program communicate better, increase incentive amounts, and improve the quality of core-services products.

2.1 Program Satisfaction

2.1.1 End-User Participant Surveys – Program Satisfaction

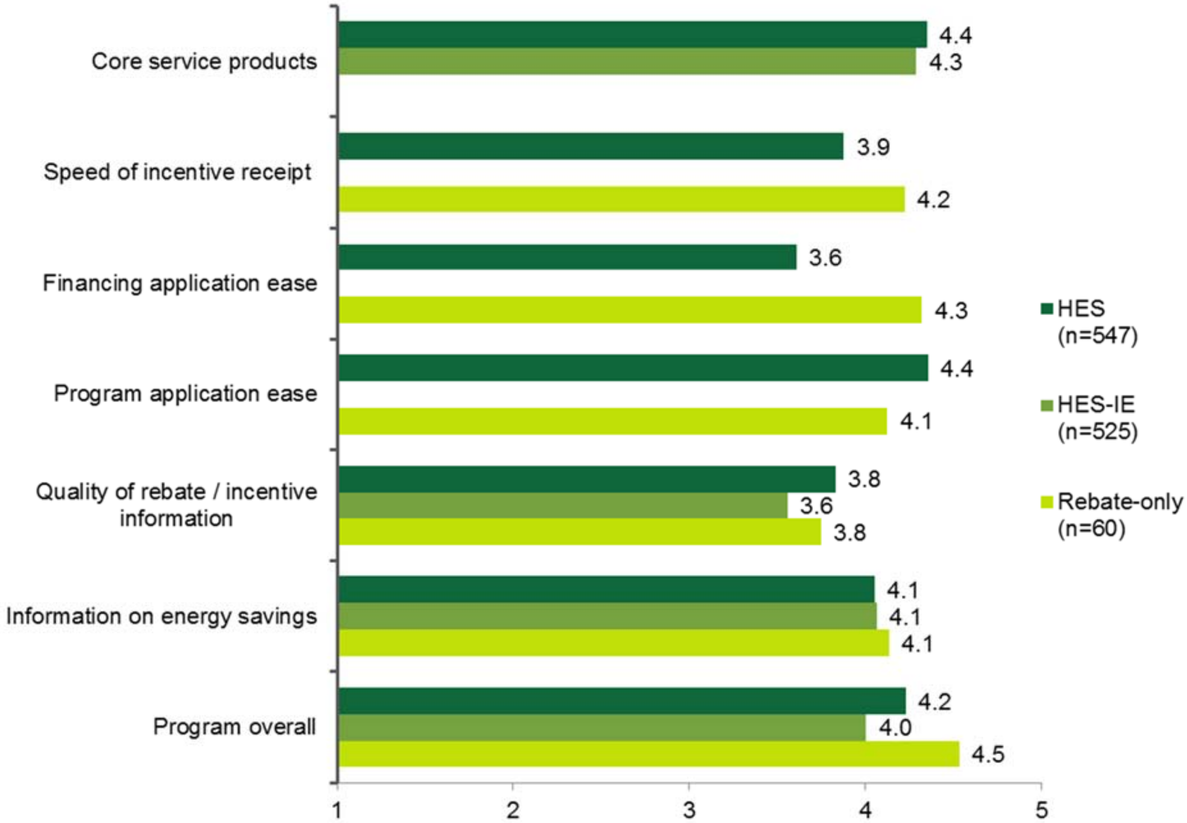
➢ ***End-user participants are highly satisfied with the program overall, and particularly with core services and the rebate applications; however, some express disappointment with the quality of rebate/incentive information.***

The majority of HES (80%), HES-IE (72%), and rebate-only (93%) end-user participant respondents were highly satisfied with their overall experience in the program.[59] As illustrated in Figure 5, their mean ratings varied by program element:

- **Core services.** Both HES and HES-IE respondents gave their highest average satisfaction ratings to the core service products, respectively rating them 4.4 and 4.3 on a scale of 1 to 5.
- **Program application.** HES respondents gave an equally high average satisfaction rating (4.4) to the ease with which they filled out the program applications; rebate-only respondents also rated this program element relatively highly (4.1).
- **Financing application.** HES respondents gave their lowest satisfaction ratings (3.6) to the ease with which they filled out the financing application; however, rebate-only respondents gave this their highest satisfaction ratings (4.3).
- **Rebate and incentive information.** Respondents gave relatively low satisfaction ratings to the quality of the rebate and incentive information, with HES-IE (3.6) and rebate-only (3.8) respondents rating it the lowest compared to all other elements.

[59] Responses of 4 or 5 on a 5-point scale, where 1 equals “not at all satisfied” and 5 equals “very satisfied,” represent high satisfaction.

Figure 5: Participant End-User Survey Respondents – Average Satisfaction



Note: Responses are weighted. Sample sizes vary across topic areas based on relevance.

- ***Short-term respondents are significantly more satisfied with program information and core services, possibly signaling program improvements or superior recall due to more recent participation.***

Short-term respondents were statistically more likely to be highly satisfied with some elements of program participation. In particular, HES short-term respondents were significantly more satisfied than HES long-term respondents with the quality of program information on energy savings (90% versus 73%), the quality of information on rebates and incentives (80% versus 64%), and with core-service product quality (90% versus 80%). While neither HES-IE group was overwhelmingly satisfied with the quality of program information on rebates and incentives, HES-IE short-term respondents (65%) were significantly more satisfied than long-term respondents (51%) with this element.

Table 19: Participant End-User Survey Respondents – Satisfaction by Survey Timing

(Percentage rating 4 or 5)

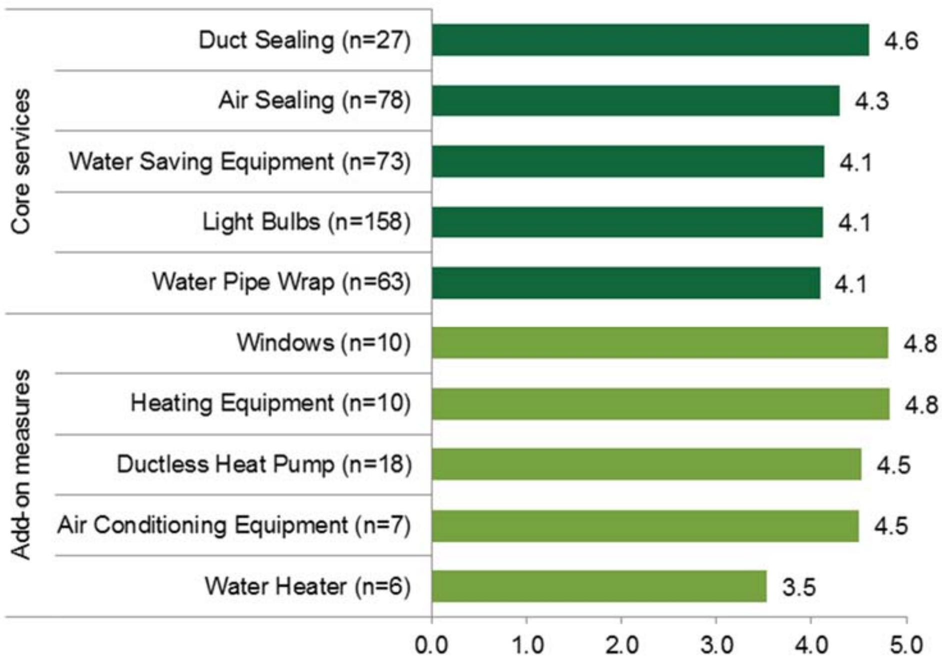
Program Element	HES		HES-IE	
	Short-term (n=55)	Long-term (n=492)	Short-term (n=125)	Long-term (n=400)
Program overall	87%	80%	75%	71%
Information on energy savings	90%*	73%	76%	72%
Quality of rebate/incentive information	80%*	64%	65%*	51%
Program application ease[1]	57%	81%	-	-
Financing application ease[1]	75%	44%	-	-
Speed of incentive receipt	60%	51%	-	-
Core service products	90%*	80%	82%	82%

Note: Responses are weighted. Sample sizes vary across topic areas based on relevance.
* Indicates that short-term respondents were significantly more likely than long-term respondents to be satisfied at the 90% confidence level.
[1] While notable differences exist, sample sizes are too small to draw significant conclusions.

- ***HES end-user participants report strong satisfaction with insulation and other program measures.***

As Figure 6 shows, respondents were very satisfied with their program measures (using the same 5-point scale). Across all measures, the weighted average satisfaction rating was 4.2. For nearly all measures, satisfaction was above 4.0.

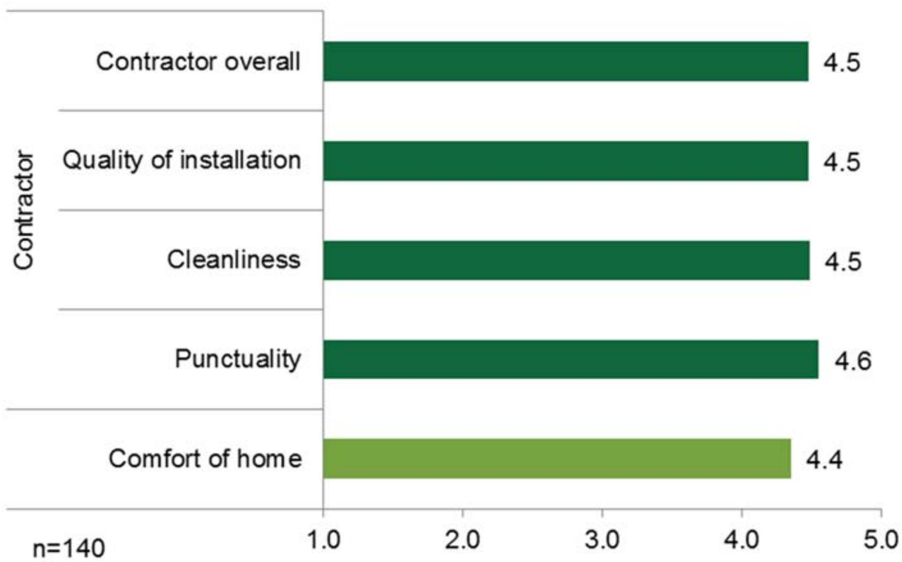
Figure 6: HES Participant End-User Survey Respondents – Satisfaction with Installed Measures



Note: Responses are weighted. Sample sizes are small (particularly for add-on measures) because, in an effort to minimize respondent fatigue, questions regarding measure satisfaction were asked only of individuals who responded to the free ridership module about that particular measure.

HES end-user respondents expressed strong satisfaction with their insulation contractors, when it came to the quality of the installation and the contractor's cleanliness and punctuality. They also were quite satisfied with the comfort level resulting from the insulation (Figure 7).

Figure 7: Participant End-User Survey Respondents – Satisfaction with Insulation



2.1.2 HES-IE Landlord and Property Manager Interviews – Program Satisfaction

➢ ***Landlords and property managers are highly satisfied, particularly with vendors, add-ons, and assessment reports.***

Interviews asked landlords and property managers to rate their level of satisfaction with various aspects of the HES-IE program on a scale of 1 to 5, where 1 equaled “not at all satisfied” and 5 equaled “very satisfied.” Figure 8 on the next page displays their average ratings and the percentage of interviewees who indicated satisfaction with a rating of 4 or 5. The average satisfaction rating for each aspect of the program was at least 4.0, indicating high levels of program satisfaction.

> “I think that [the HES-IE program] is a win-win for everyone: [the utility], the tenant, and the landlord.”
>
> *– HES-IE landlord participant*

- **Overall satisfaction.** Landlords and property managers were very satisfied with the program overall: 93% rated it a 4 or 5, making positive statements such as “I’m very happy with the outcome of the program and look to use it again.” On average, they rated the program a 4.4 on a 5-point scale. However, they were not as satisfied with the energy savings that they saw from the program, rating this aspect a 4.0, on average.
- **Contractor experiences.** Landlords and property managers were also highly satisfied with their interactions with the contractors. All respondents rated this a 4 or 5, with an average of 4.8. Interviewees described the contractors as “easy to work with” and “wonderful.” One interviewee added:

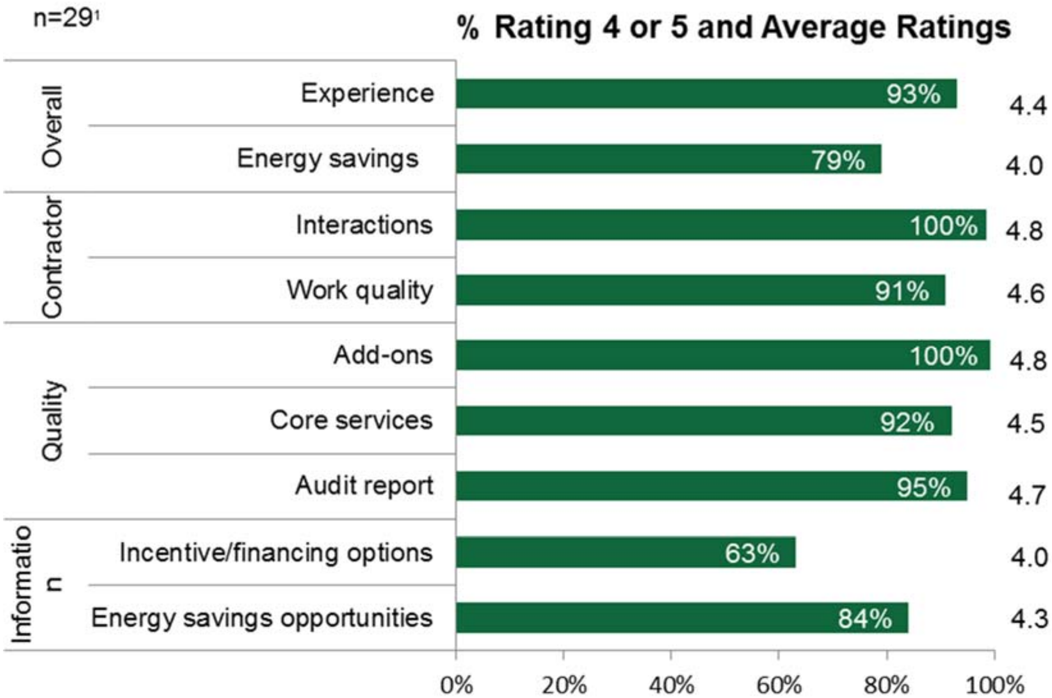
> *The [vendor staff] were people that I would have considered hiring if they weren't already working [for another company]. All of the residents had positive feedback about the [technicians] who did the work in the units.*

- **Quality.** Landlords and property managers were very satisfied with the quality of the add-on measures and quite satisfied with the quality of the core services (basically the same measures as offered to single-family participants)[60]; 100% rated add-on measure quality 4 or 5, averaging 4.8. The vast majority of interviewees were satisfied with the core services (92%), noting that they did not receive complaints and they have found that tenants are "happy" with the free measures. Interviewees thought the quality of the assessment report was great, finding it "clear," "comprehensive," and "quite informative"—95% gave it a rating indicating they were satisfied.
- **Information dissemination.** While the average satisfaction rating was 4.0 for the information about incentives and financing options—indicating satisfaction—landlords and property managers were least likely to be satisfied with this aspect of the program: 63% assigned a rating of 4 or 5. One interviewee who provided a low rating explained:

> *I didn't understand [the incentive and financing opportunities] all too well, so I didn't take advantage of it. It seemed a little complicated to get involved with.*

[60] Predominantly lighting, direct hot water, air sealing, and duct sealing. However, HES-IE participants, including landlords and property managers, are sometimes eligible for a greater number of free add-on measures (i.e., deeper measures) that are not part of the core services typically offered to participants in HES and HES-IE participants. Refrigerators are one of the most common add-on measures that HES-IE participants might receive for free.

Figure 8: HES-IE Landlord and Property Manager Interviewees – Program Satisfaction Ratings



Note: Interviewees rated their level of satisfaction on a scale of 1 to 5, where 1 equaled "not at all satisfied" and 5 equaled "very satisfied."
[1] Sample sizes vary across categories if topic areas were not applicable.

2.1.3 End-User Data Analysis – Participant Wait Time

Using the Eversource HES[61] participation database (from July 2013 through April 2015), the study estimated the mean and median wait times that participants experienced from the time that they requested a home energy assessment to the date on which they received the assessment.[62] Among HES participants, the average (mean) wait time was 22 days, though the distribution of wait times had a fairly high degree of skew, evidenced by the substantively smaller median wait time of 14 days. In other words, most participants received services rather quickly, but a few had to wait substantially longer. As Table 20 shows, five vendors had average HES participant wait times of one month or more (greater than or equal to 30 days); these five vendors served 3,303 customers, or about 14% of the Eversource core services recipients.

[61] Neither Eversource HES-IE data nor UI HES and HES-IE data included the date (or vendor name) variables necessary to conduct this analysis.
[62] For a small percentage (1%) of projects, the date the customer requested services was listed as being after the receipt of core services. A similar percentage (3%) of records had the same date the customer requested as the recorded date of core services receipt. The wait time estimates excluded these records. Appendix 2.1.3 presents the share of excluded records, by vendor.

Table 20: HES End-user Average Wait Time between Scheduling and Receiving Assessment, by Vendor

Vendor Name	Records / Projects	Mean Wait Time (Days)	Median Wait Time (Days)
A Plus Installation, LLC	427	35	23
Aiello Home Services	925	23	13
BCB Conservation Group, LLC	429	18	14
Climate Partners, LLC	154	26	21
Competitive Resources, Inc.	1,215	30	23
EcoSmart by R Pelton Builders, Inc.	1,905	15	10
Energy Efficiencies Solutions, LLC	1,595	25	19
Energy Resource Group	720	36	26
EnergyPRZ, LLC	1,441	21	16
Fox Heating Services, Inc.	322	41	35
Greenbuilt Connecticut	192	16	10
Gulick Building & Development, LLC	541	20	14
Handyman Express Energy Solutions LLC	419	41	38
Hoffman Fuel	193	24	19
Home Doctor of America	388	15	4
Lantern Energy, LLC	1,143	20	14
Molina & Associates, Inc.	279	21	10
New England Conservation Services, LLC	1,098	25	19
New England Smart Energy Group, LLC	1,730	21	14
Next Step Living, Inc.	3,548	17	6
R&W Heating, LLC	253	29	25
Santa Fuel, Inc.	415	26	15
Tri City Home Energy Services	371	15	9
Uplands Construction Group, LLC	404	20	16
Victory Industries, LLC	1,431	20	7
Wesson Energy, Inc.	1,356	28	18
Other Vendors[1]	75	24	17
Total	**22,969**	**22**	**14**

[1] Vendors with fewer than 100 records have been combined into the "other" category.

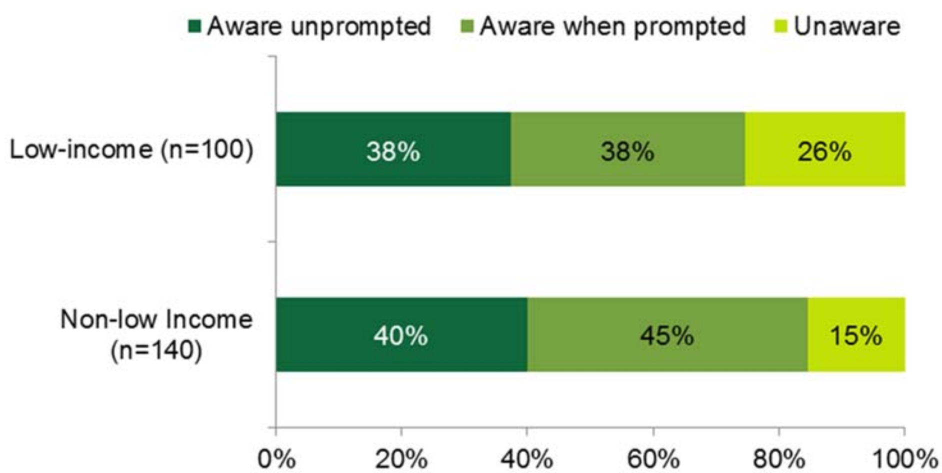
2.2 Program Awareness

➢ ***HES / HES-IE nonparticipant end-users reported strong awareness of the programs.***

The majority of rebate-only end-user participants (83%) stated that they were aware of the HES program. Additionally, end-users who had responded to the nonparticipant survey were sometimes aware of the program—either prompted or unprompted (Figure 9). Between both prompted and unprompted responses, low-income nonparticipants were somewhat less aware of the program (75%) than NLI nonparticipants (85%).

Figure 9: Nonparticipant End-user Survey Respondents – HES / HES-IE Program Awareness

(Percentage of respondents)



2.3 Program Marketing and Outreach

2.3.1 End-User Participant Surveys – Marketing and Outreach

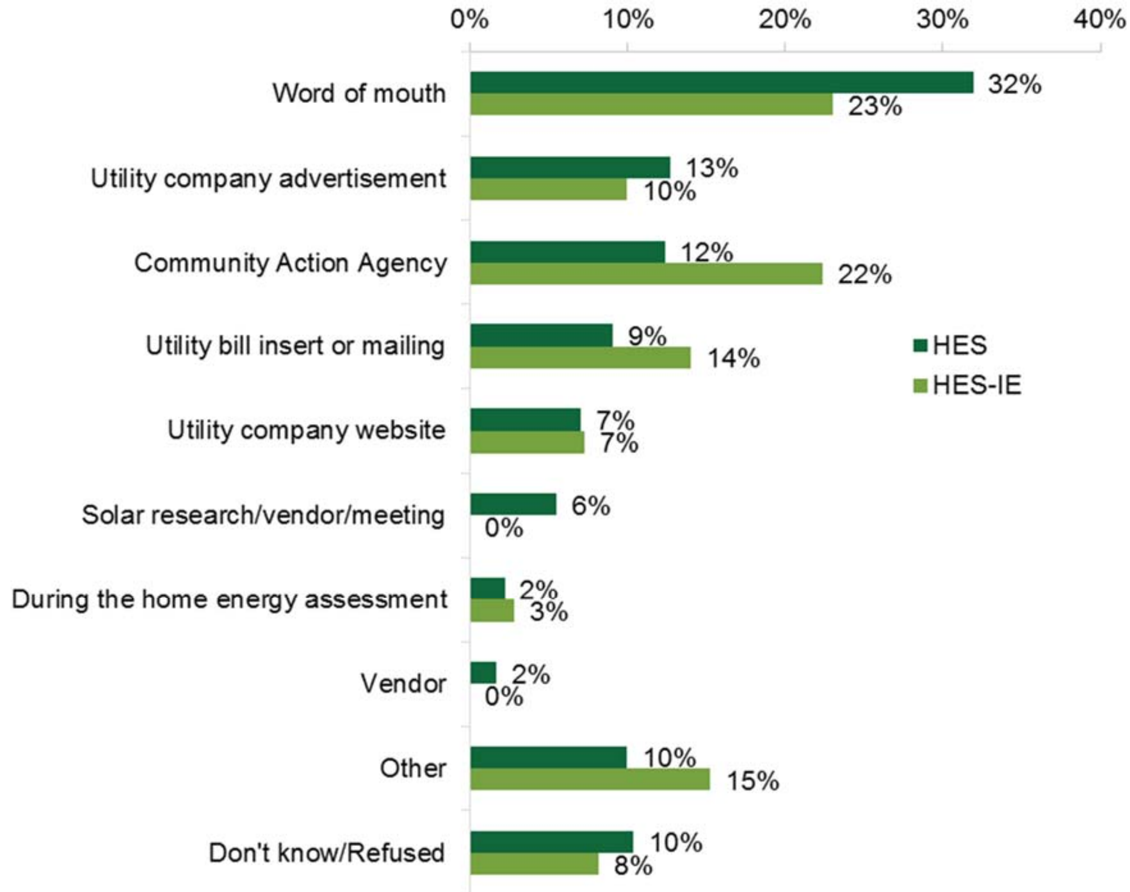
- ***HES and HES-IE end-user participants most often learned about the program through word of mouth and learned of rebates and incentives through the assessments.***

As shown in Figure 10, HES (32%) and HES-IE (23%) end-user participants most frequently reported that they learned about the program from family and friends (i.e., word of mouth). Other commonly cited sources of information about the program include utility advertisements (13% in HES and 10% in HES-IE), Community Action Agencies (CAAs; 12% in HES and 22% in HES-IE), and utility bill inserts or mailings (9% in HES and 14% in HES-IE).

HES and HES-IE respondents most often learned about utility *rebates and incentives* during the energy assessment. Rebate-only end-users most often learned of program rebates through their installation contractors or vendors. (See Appendix A.2.1 for more details.)

Figure 10: Participant End-user Survey Respondents – Channels of Program Awareness

(Percentage of respondents)



Note: Percentages are weighted.

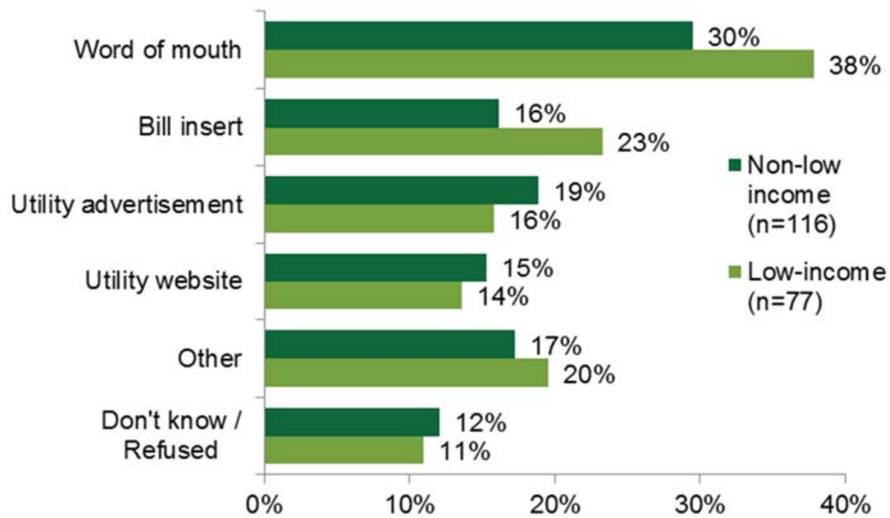
2.3.2 End-user Nonparticipant Surveys – Marketing and Outreach

- ***Nonparticipant end-users learned of the program through word of mouth, bill inserts, and other utility advertisements.***

Low-income (38%) and NLI (30%) nonparticipant end-user respondents most often learned of HES/HES-IE through word of mouth (Figure 11). Compared to other channels, low-income respondents were next most likely to have learned of the program through bill inserts (23%) and NLI respondents through utility advertisements (19%).

Figure 11: Nonparticipant End-user Survey Respondents – Channels of Program Awareness

(Percentage of respondents aware of the program)



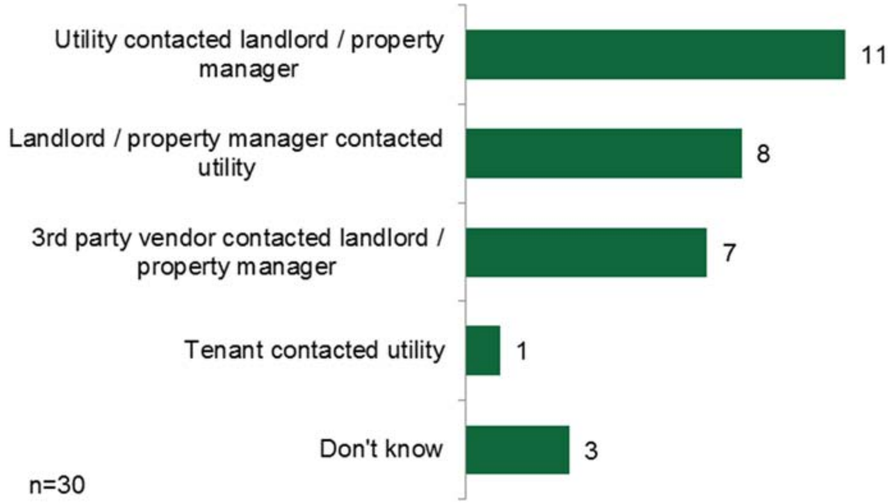
2.3.3 HES-IE Landlord and Property Manager Interviews – Marketing and Outreach

- ***Utility outreach to landlords and property managers is the most common program entry point.***

HES-IE landlord and property manager interviewees were most likely to enter the program after being contacted by the utility company (Figure 12). Over one-third (eleven) of the 30 interviewees originally became involved with the program after the utility contacted them or other staff members at their company. The next most common channels were the landlord/management staff contacting the utility (eight) and a third-party vendor or contractor, such as HES-IE program vendors or insulation contractors, soliciting the landlord or property manager (seven).

Figure 12: HES-IE Landlord and Property Manager Interviewees – Channels to Participation

(Count of responses)


Utility contacted landlord / property manager
11
Landlord / property manager contacted utility
8
3rd party vendor contacted landlord / property manager
7
Tenant contacted utility
1
Don't know
3
n=30

2.4 Program Participation Drivers and Barriers

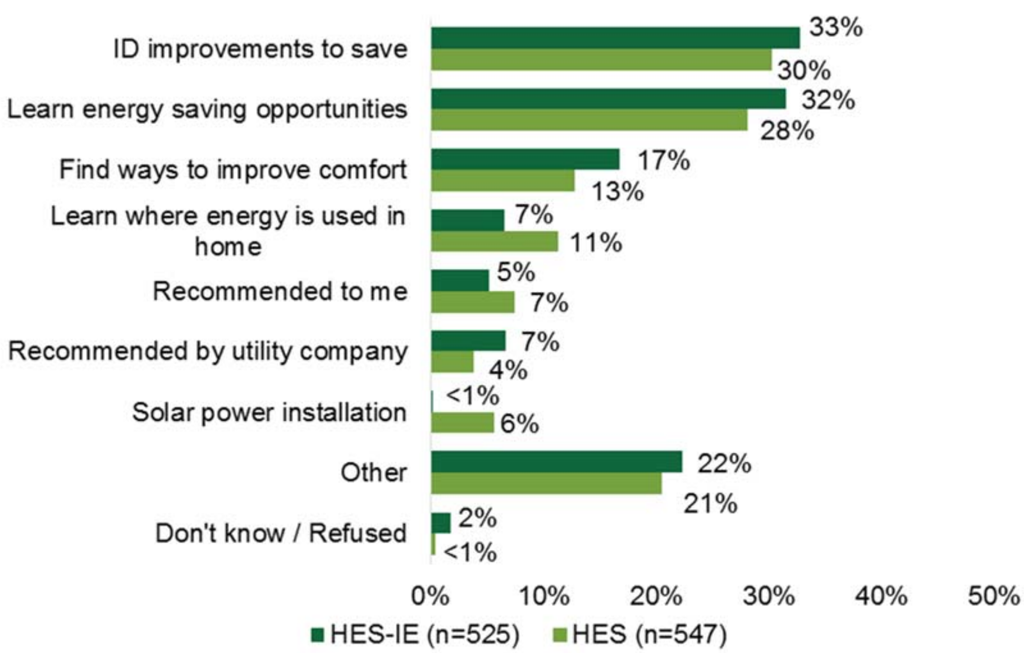
2.4.1 End-User Participant and Nonparticipant Surveys – Drivers and Barriers

- ***End-user participants are driven to participate in order to identify ways to save money on energy costs and learn about energy saving opportunities.***

When asked why they signed up for the assessment, HES and HES-IE end-user participants primarily indicated a desire to identify ways to save the most money (30% of HES and 33% of HES-IE participants) and to learn about energy-saving opportunities (28% of HES and 32% of HES-IE participants). Notable proportions of HES (13%) and HES-IE (17%) end-users also reported that they participated because they wanted to find ways to make their homes more comfortable. Respondents who participated because they wanted to see if they were eligible for an incentive or rebate often were interested in windows and insulation.

Figure 13: HES / HES-IE End-User Participant Survey Respondents – Motivations to Participate

(Multiple responses, percentage of respondents)

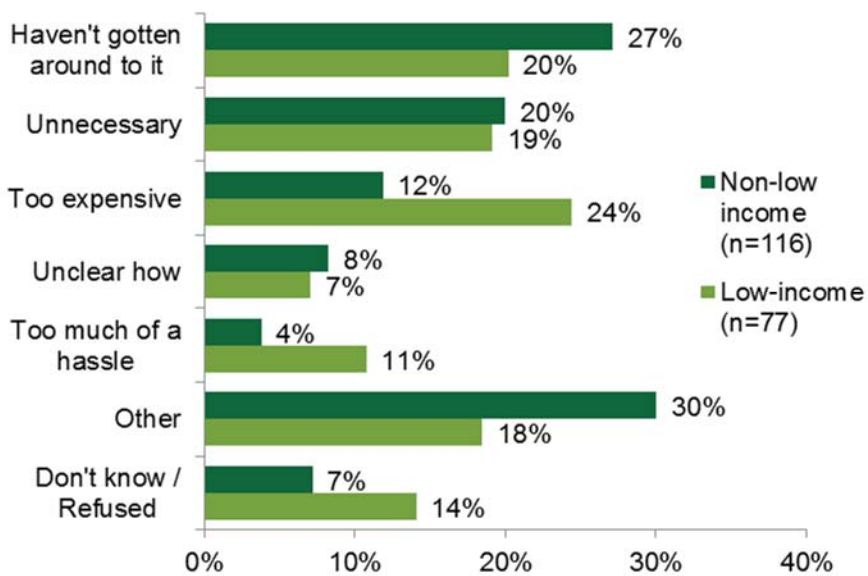


- ***Nonparticipant end-users do not participate because they have not made energy efficiency a priority, do not see a need, or find the cost to be prohibitive.***

As illustrated in Figure 14, NLI nonparticipant respondents most often did not participate because they "had not gotten around to it" (27%) or felt that it was unnecessary (20%). Low-income nonparticipants were held back because they found it to be too expensive (24%) or they did not think it was necessary (19%).

Figure 14: Nonparticipant End-user Survey Respondents – Reasons for Nonparticipation

(Percentage of respondents aware of program)



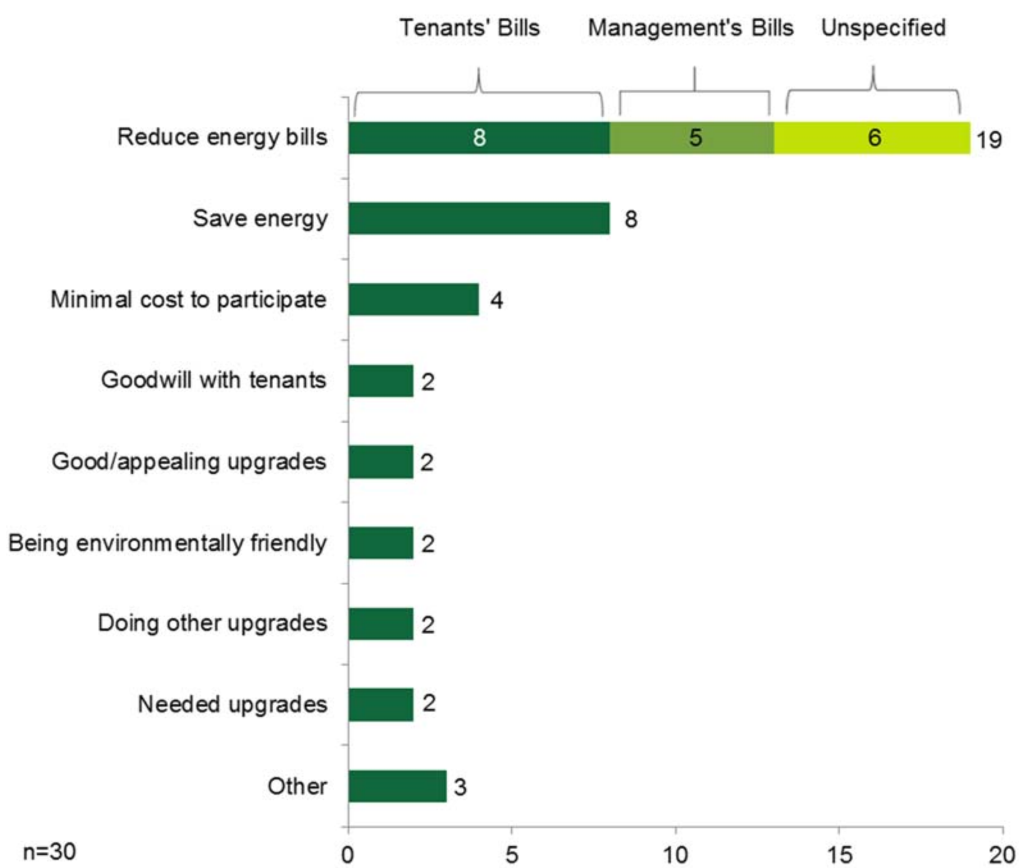
2.4.2 HES-IE Landlord and Property Manager Interviews – Drivers and Barriers

- ***Reducing energy bills is a top driver of landlord/property manager participation.***

HES-IE landlord and property manager interviewees most commonly participated in the program out of a desire to reduce energy bills for their tenants (eight interviewees), themselves (five), or in general (six). The next most common reason was to save energy (eight), followed by the minimal cost to participate in the program (four). Interviewees were also motivated to participate in an effort to develop goodwill with tenants, receive upgrades that they found appealing, create room in their budgets to make other non-energy upgrades, and to install what they believed to be specific and necessary program measures such as insulation or lighting equipment (Figure 15).

Figure 15: HES-IE Landlord and Property Manager Interviewees – Motivations to Participate

(Multiple responses, count of responses)



As mentioned above, landlords and property managers were driven to participate in the HES-IE program to reduce energy bills and save energy. Interviews asked them to rate the importance of the anticipated savings in their buildings' energy bills and their tenants' energy bills on their decision to participate. On a scale of 1 to 5, where 1 means "not at all important" and 5 means "very important," they gave an average importance rating of 4.5 for their own energy bills (n=28) and 4.5 for their tenants' energy bills (n=23).[63] After rating the importance of reducing tenants' bills as a 5.0, one property manager explained the rationale behind it:

[63] Interviewees did not provide ratings respectively if the program activities would not impact the overall building energy bill (from their perspective) or if the tenants did not pay any energy bills.

I mean, it is low-income housing and some people struggle, especially in the winter with the electric heat. So the more reasonable [tenants' living] costs are, the higher the likelihood of us receiving our rent is.

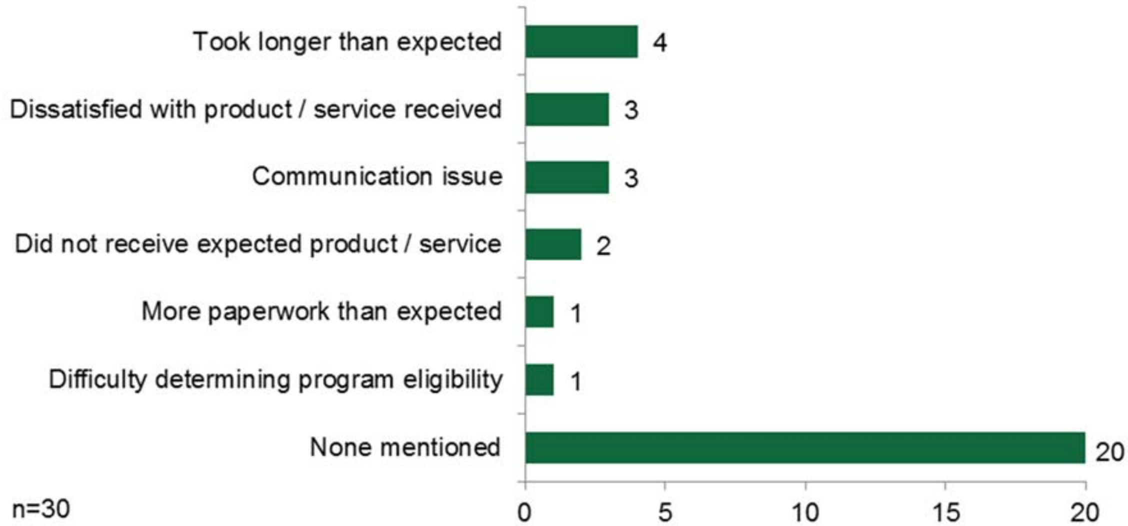
➢ ***Landlords and property managers had few obstacles to participation, only mentioning issues with timing, quality, and communication.***

As illustrated in Figure 16, only one-third of the HES-IE landlord and property manager interviewees (ten) identified difficulties or challenges during their involvement in the program.

- **Time span.** Most often, they found that the entire process took longer than expected. Four said it took months to schedule installations or that the project lasted for more than one year.
- **Measure quality.** Only three interviewees were less than 100% satisfied; these three voiced concerns that the screw-based CFLs were not bright enough and the circline fixtures' bulbs were expensive to replace, that there was "sloppy" contractor work, and that tenants complained that they did not visually observe major improvements.
- **Communications.** Three interviewees expressed frustration with program communications, including unreturned phone calls and emails to a program contact, discontinuity in communication following the retirement of a program staff member, and a lack of communication with the contractor about important details of the work. That said, one interviewee made a point to comment on the positive communication with the program staff and vendors, saying, "The people I've worked with have been excellent."

Figure 16: HES-IE Property Manager and Landlord Interviewees – Participation Challenges

(Multiple responses, count of responses)



2.5 Energy Savings Experiences

➢ ***End-user participants self-report reductions in energy consumption.***

Home energy assessment programs such as Connecticut HES/HES-IE programs are generally expected to save between 10% and 15% of household energy usage.[64] While entirely self-reported, HES respondents estimated a 10% decrease and HES-IE respondents estimated a 9% decrease, on average. Over one-fifth of HES and HES-IE respondents did not know how or if their energy consumption had changed since participating; however, the majority of those who were familiar with their consumption saw a decrease. As illustrated in Figure 17, over one-half of all HES respondents reported a decrease (54%), and about two-fifths of all HES-IE respondents reported a decrease (43%). Rebate-only respondents were less familiar with their consumption, but those who were familiar estimated that, on average, their consumption had decreased by 22%.

Figure 17: End-user Participant Survey Respondents – Changes in Energy Consumption following Program Participation

(Percentage of respondents and mean change)

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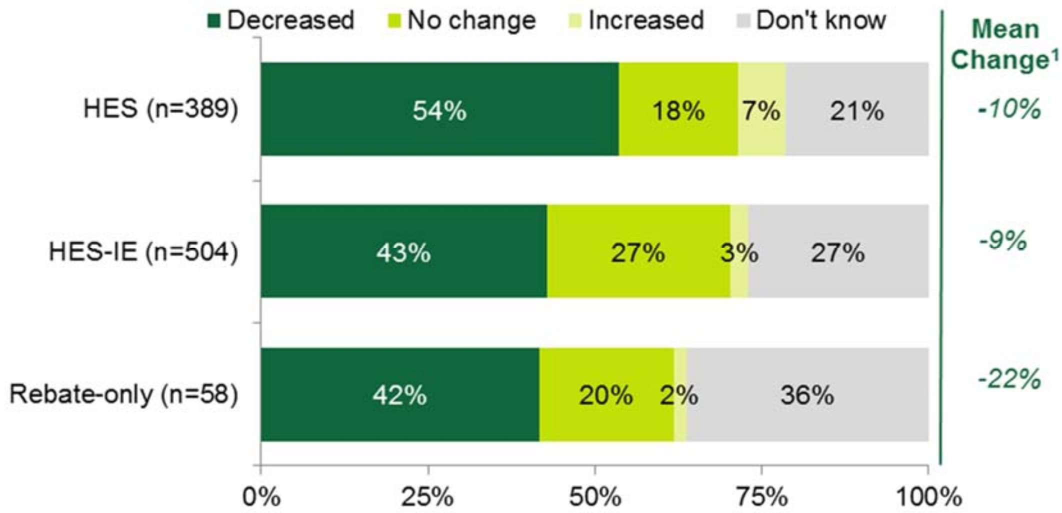
[64] Estimated developed through values reported in the R16 HES and HES-IE Impact Evaluation and subsequent conversations among evaluation team members. See R16 study at http://www.energizect.com/your-town/hes-and-hes-ie-impact-evaluation-r16-final-report-12-31-14.



Note: Values are weighted.

[1] Denotes the average change that respondents reported seeing in their energy usage following program participation; excludes values more than three standard deviations from the mean.

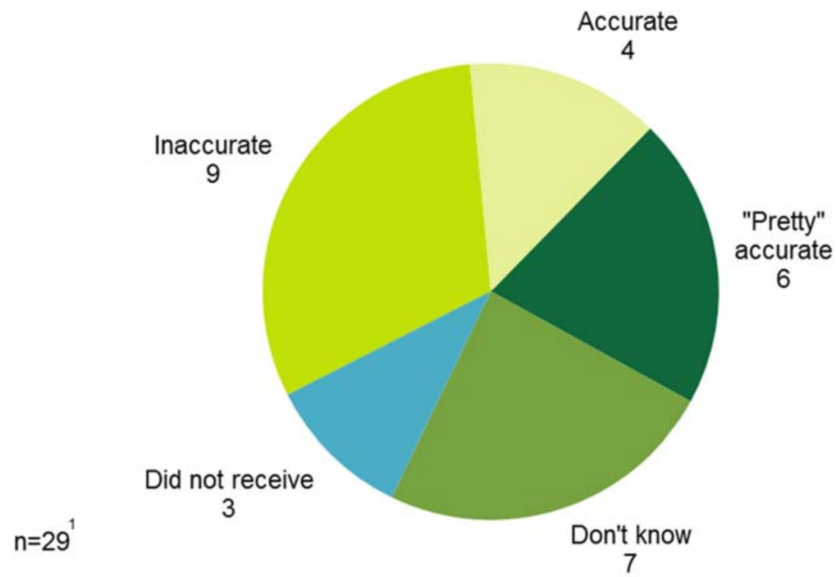
2.6 Energy Savings Expectations

➢ ***Landlords voiced mixed perceptions of the accuracy of energy savings estimates.***

Ten of the 29 landlords and property managers initially thought that the vendors' estimates of the possible savings that they could reap from making energy efficiency upgrades through the program (prior to the upgrades being performed) would be accurate (four) or "pretty" accurate (six), and nine interviewees thought that they were inaccurate. Those interviewees who thought that the estimates were inaccurate generally thought the vendors overestimated savings (six of nine); for the most part, they thought that, prior to the upgrades being performed, the actual savings would have been between 15% and 30% lower than what the vendor was suggesting at the time. The three who thought the savings would be higher estimated that they would be between 15% and 23% higher.

Figure 18: HES-IE Landlord and Property Manager Interviewees – Initial Perceptions of Vendors' Energy Savings Estimates

(Count of respondents)



Note: The telephone interview guide asked interviewees, “At the time that the utility gave you an estimate of the expected savings on your overall building energy bill, how accurate did you think that estimate was?”

[1] The in-person interview guide did not ask this question; as such, only 29 interviewees answered this question.

2.7 Participant Suggestions for Improvement

2.7.1 End-User Participant Surveys – Suggestions for Improvement

- ***End-users have had good experiences with the program, but suggest improving program information sharing and advertising, improving work quality, and expanding offerings.***

When asked for program feedback, HES (10%) and HES-IE (34%) respondents were most likely to report that, in fact, they had good experiences with program. HES-IE respondents were most likely to suggest that the quality and completeness of work be improved (15%)[65] and to expand program offerings to include additional measures (12%).[66]

Respondents offered other suggestions, that—broadly speaking—encouraged expanding and clarifying program information, sharing more information (including advertising), and expanding program offerings.

Table 21: End-user Participant Survey Respondents – Suggestions for Program Improvement

(Multiple response, percentage of respondents)

Feedback	HES (n=114)	HES-IE (n=125)	Rebate-only (n=60)
Improve / increase information about topic			
Advertise	8%	5%	5%
Structure of rebates and program	4%	4%	14%
Energy savings / usage	3%	2%	3%
Financing	1%	-	-
Timing of work	-	3%	-
Fuel conversion	-	-	2%
Program process feedback / suggestions			
Good experience	10%	34%	10%
Make the process faster	< 1%	3%	3%
Perform follow-up visits	-	1%	-
Provide vendors with IDs	-	< 1%	-
Program structure suggestions			
Expand program measure offerings	7%	12%	2%
Increase rebate amounts	1%	2%	5%
Expand eligibility requirements	< 1%	2%	-
Keep rebates the same	-	-	5%
Work quality feedback / suggestions			
Use better quality products	3%	2%	-

[65] For example, some said that they had been told that technicians would come back to make additional improvements or finish improvements, but the vendors had either not followed up or the participant had not been able to get in touch with the vendors despite following up themselves. At least five participants that were having insulation or wanted insulation installed mentioned the inadequacy or incompleteness of the work.
[66] Their suggestions included new roofing, insulation (already offered), new doors, windows (already offered), additional light bulbs, annual furnace cleaning, etc.

Work was inadequate / incomplete	1%	15%	-
Vendor damaged property	1%	2%	-

Note: Percentages are weighted. Sample sizes are small because this question was asked of short-term respondents only.

2.7.2 HES-IE Landlord and Property Manager Interviews – Suggestions for Improvement

➢ ***Landlord suggestions include better communication, increased incentive amounts, and improved quality of core-services products.***

HES-IE landlords and property managers had few complaints and, as a result, few suggestions for program improvement. Six of the fifteen landlord and property manager interviewees who offered suggestions to improve the program recommended improving the HES-IE program communications (Figure 19). In particular, they suggested that the utilities undertake the following activities:

- Create a single contact for all program-related communications.
- Clearly convey what to expect from the contractors.
- Communicate more clearly about timelines up front.
- Emphasize possible costs and savings associated with program improvements during the solicitation process to increase participation rates.
- Carry out more direct communication as opposed to relying on third-party contractors.

The interviewee who suggested increasing the direct communication desired more confirmation of the legitimacy of the vendors' recommendations, stating:

> *We were contacted [initially] by the contractor, and you just wonder whether the contractor is trying to sell you something that you really don't need.*

Other interviewees suggested the following:

- Increase financial incentives for windows (four), exterior lighting equipment, and refrigerators.
- Improve the quality of core-services (four), including additional air sealing in residential units, using caulking in place of foam for very small air-sealing jobs, using brighter light bulbs, and using LEDs instead of CFLs.
- Add products and services to the program (three), such as door sweeps (which are already installed where needed), kitchen stoves,[67] and incentives for renewable energy measures.

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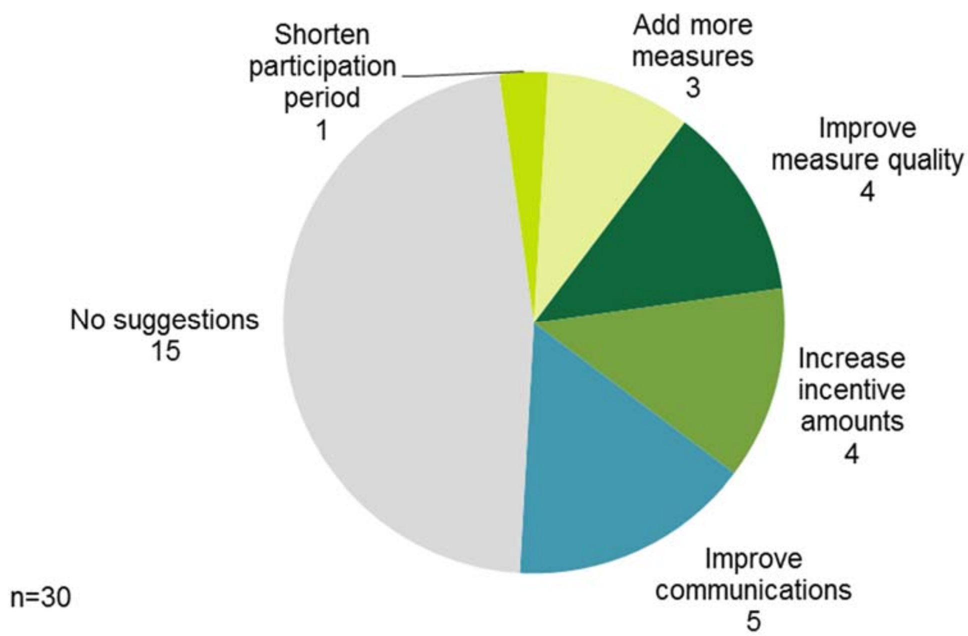
[67] It is not apparent that there are any residential programs in Connecticut or elsewhere that support residential kitchen stoves, almost certainly reflecting the fact that ENERGY STAR® does not currently have specifications—and therefore qualified models—for residential kitchen stoves.

Figure 19: HES-IE Landlord and Property Manager Interviewees –Suggestions for Program Improvement

(Multiple responses, count of responses)



2.8 Benchmarking – Program Processes

➢ ***Awareness among nonparticipants is high compared to other programs; satisfaction is about average, but better when it comes to satisfaction with core services and lower when it comes to quality of information.***

This study involves a benchmarking task in which its results are compared to other studies that assess similar NLI[68] home energy assessment programs in the Northeast. Table 22 benchmarks some of the R4 process findings against other studies:

- **Awareness.** When it came to nonparticipant awareness, Connecticut customers were significantly more aware of the HES program than were New York customers of the Green Jobs – Green New York (GJGNY) Home Performance with ENERGY STAR® (HPwES) program.[69] The share of Connecticut rebate-only participants who

[68] The benchmarking activity is limited to non-low-income programs because of the limited research that has been performed on low-income programs.
[69] Note that HPwES program structure is not perfectly comparable to HES program structures; however, they both involve home energy assessments that make recommendations for deeper measures.

were aware of the HES program was exactly the same as the percentage of their counterparts in Massachusetts[70] were of its Home Energy Services (HES) program.

- **Satisfaction.** Connecticut HES participants are generally as satisfied with HES as participants in New York, Efficiency Vermont (EVT) and Vermont Gas System (VGS), Efficiency Maine (ME), and Massachusetts HES are with their programs. Connecticut HES participants were more likely to be satisfied with the quality of the core services they received than were Massachusetts HES participants with theirs.[71] Connecticut HES participants, however, were notably less likely than Efficiency Maine participants to be satisfied with the information that they received from the program about energy savings or rebates and incentives.

[70] The Massachusetts counterparts were customers that were participants in the program administrators' Residential Heating and Water Heating program (HEHE) or Residential Heating and Cooling program (COOL SMART) that had not taken part in the Massachusetts HES program.

[71] It should be noted that the core service measures compared are somewhat different. The satisfaction rate associated with the Massachusetts study assessed portable measures such as LEDs, CFLs, water saving measures, and programmable thermostats, excluding air sealing and duct sealing. Additionally, the Connecticut HES program does not include programmable thermostats.

Table 22: Program Process Results – Benchmarking

Benchmarking Parameter	Comparison Program		Connecticut HES Value	Notes / Considerations
	Program	Value		
Awareness				
Percentage of nonparticipants aware of program (prompted)	Green Jobs – Green New York (GJGNY)[1]	36%	81%	NY HPwES program structure is not perfectly comparable to the CT HES program structure; however, both involve home energy assessments that make recommendations for deeper measures.
Percentage of rebate-only participants aware of HES	Massachusetts Home Energy Services (MA HES)[2]	83%	83%	The CT rebate-only users represented respondents with numerous measure types; the MA study was limited to respondents receiving particular HVAC incentives.
Percentage of Participants Satisfied (ratings of 4 or 5 on a 5-point scale)				
Program overall	Vermont Public Service Department (VT PSD)[3]	90% and 88%	80%	Also uses a 5-point scale; Efficiency VT (90%) and VT Gas Systems (88%) had slightly different results.
	Efficiency Maine (ME)[4]	86%		Efficiency ME uses a 10-point scale; the study considers ratings of 7-10 as satisfied.
	GJGNY	82%		Both use 5-point scales.
	MA HES	75%		MA uses a 4-point scale; the study considers ratings of 3 and 4 as satisfied.
Quality of core-service measures	MA HES	74%	80%	The MA rating assessed only portable measures (excluding air sealing and duct sealing), including programmable thermostats (not offered by CT) in addition to light bulbs and water saving equipment (offered by CT).
Quality of information in assessment report	Efficiency ME	86%	65% and 74%	This CT study obtained values for information about energy savings (65%) and information about rebates and incentives (74%).
Ease of filling out program application	GJGNY	86%	79%	-
Quality of work	Efficiency ME	83%	86%	Efficiency ME and GJGNY percentages represent the percentages satisfied with the work generally, but this CT study only assessed quality of work for insulation.
	VT PSD	90% and 75%		
Installation contractor	GJGNY	93%	85%	GJGNY percentage represents the percentage satisfied with installation contractors for numerous measures, but this CT study only assessed quality of work for insulation.

[1] NMR. *Process Evaluation and Market Characterization and Assessment: Green Jobs – Green New York Residential Program*. September 2012.
[2] Cadmus. *Massachusetts Home Energy Services Initiative and HEAT Loan Delivery Assessment*. July 31, 2015. http://ma-eeac.org/wordpress/wp-content/uploads/HES-and-HEAT-Loan-Program-Assessment-Final-Report.pdf.
[3] GDS Associates, Inc. and Research into Action. *Vermont Single-Family Retrofit Market Process Evaluation*. February 20, 2013.

[4] Opinion Dynamics and Dunsky Energy Consulting. *Evaluation of the Efficiency Maine Trust PACE, Power Saver, and RDI Programs. Final Evaluation Report. Volume II: Residential Direct Install Program.* October 23, 2013. http://www.efficiencymaine.com/docs/RDI-Final-Evaluation-Report-FINAL.pdf.

3 Section 3 Decision Making and Financing (R46) Findings

The number and nature of energy conservation financing options available to single-family homeowners and multifamily landlords and property managers in Connecticut has increased over the past few years. At the same time, the Companies still offer their customers numerous downstream rebates for energy efficiency upgrades. The R46 study, which leveraged evaluation resources with R4 and R31, assessed decision making and financing through the use of CATI surveys with HES participants and nonparticipants. Collectively R4, R31, and R46 explored issues of awareness of, opinions about, and use of financing and rebates with participants, nonparticipants, landlords, property managers, and vendors. The main findings are as follows:

- **High awareness.** Respondents reported relatively high awareness of rebates and financing. Nonparticipant awareness of financing was high compared to a similar Northeast program.
- **Preference for rebates.** HES participants prefer rebates to financing, although the two in combination are appealing to many participants (73%).
- **Attraction to zero percent financing and aversion to debt.** While participants find zero percent financing and on-bill repayment attractive, they still seem averse to taking on debt, especially if they feel they can pay for the upgrades without a loan.
- **Ideal rebate level.** Although rebates influence measure uptake, participants would prefer that rebates cover roughly one-half of the project costs.
- **Vendor follow-up.** Vendor follow-up may be linked to insulation installation.
- **Legal language.** Legal terminology of financing materials confuses some participants.

3.1 End-User Participant Surveys – Decision Making and Financing

The CATI surveys completed as part of the R4 and R31 studies asked HES end-user respondents to assess their decision making regarding additional upgrades performed or installed based on vendor recommendations. The surveys also explored decision making about financing and rebates.[72]

[72] HES-IE end-user respondents were not asked financing and decision-making questions for two reasons. First, most deeper-measure upgrades are provided free of charge to HES-IE end users. Second, the study approach operated under the assumption that low-income customers are in less of a position to make additional energy efficiency investments on their own, even with rebates and financing options.

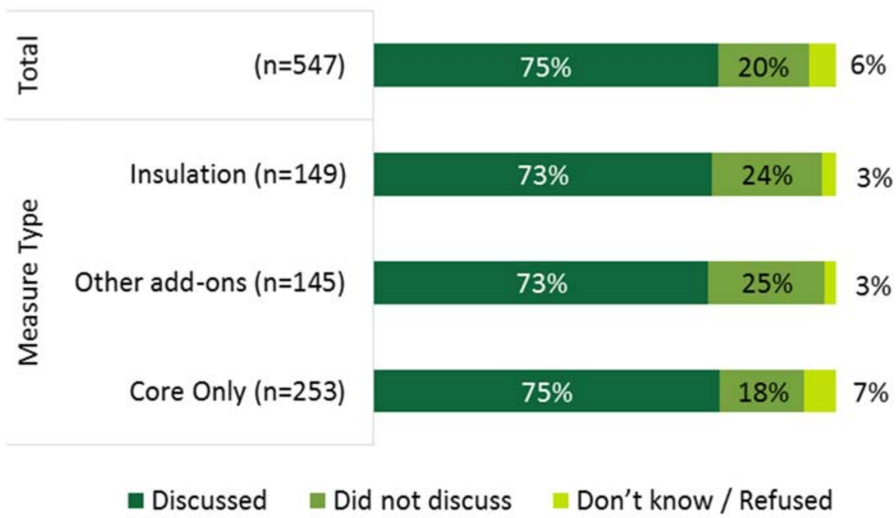
3.1.1 Motivations for and Barriers to Making Additional Improvements

- ***Vendors provide deeper measure recommendations to the majority of HES end-users, but this does not correlate with follow-through with add-on measure installation.***

Overall, three-fourths of all HES end-user respondents (75%) reported that the vendor sat down with them and discussed additional improvements that they could make. It does not appear that having a discussion with the vendor impacted respondents' likelihood to install add-on measures, given that 75% who had only core measures installed had recalled having a discussion with the vendor, and 73% of those who had insulation installed and 73% of those who had other add-on measures[73] installed recalled having a discussion with the vendor (Figure 20).

Figure 20: HES End-user Participant Survey Respondents – Vendor Discussions about Improvements

(Base = all HES respondents)



Note: Percentages are weighted.

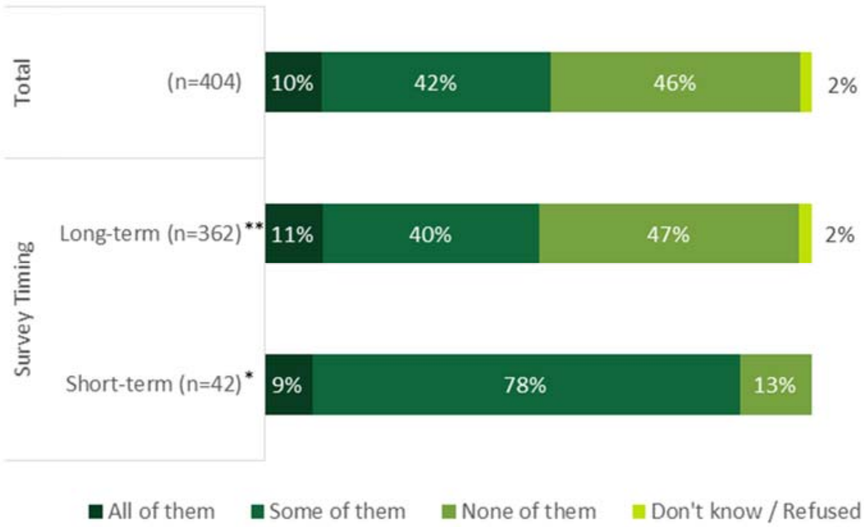
Slightly more than one-half of HES respondents who had discussions with the vendors installed either all or some of the improvements that the vendor recommended (52%). Short-term survey respondents (87%) were significantly more likely than other respondents (51%) to have made some of the improvements that the vendor recommended (Figure 21). This association may be related to improvements in vendors' sales strategies over time as they figure out how to most effectively encourage participants to make additional improvements. It could also reflect increased efforts by the vendors and Companies to

[73] For reporting purposes, comparisons across measure types in this report refer to non-insulation add-on measures as "other" add-on measures.

follow up with participants after the assessment to encourage deeper-measure uptake. Both of these possible explanations are speculative, however.

Figure 21: HES End-user Participant Survey Respondents – Additional Improvements Made

(Base = respondents whose vendor discussed additional improvements with)



Note: Percentages are weighted.
* Indicates that short-term respondents were significantly more likely to install all additional improvements than long-term respondents at the 90% confidence level.
**Indicates that long-term respondents were significantly more likely to install no improvements than short-term respondents at the 90% confidence level.

- ***Down payments and potential energy savings are pivotal factors in HES end-users' decision to install add-on measures.***

As shown in Table 23, "partial installers" (those who had installed only *some* of the recommended measures) most often chose the improvements that they made by selecting those that were the least expensive (37%) and that would save the most energy and provide the most utility bill savings (32%). When looking by measures type, core-only HES respondents were most likely to make their selection of additional measures by choosing the least expensive option (40%); given their status as "core only" installers from a program perspective, any additional measures were installed outside the program (meaning they purchased it without program incentives). Core-only respondents were also significantly more likely (25%) than those who installed insulation (10%) to base their decision on what was easiest to install. Respondents who installed insulation were more likely than others to make their decisions based on what would provide them with the greatest energy or utility bill savings (41%).

Table 23: HES End-user Participant Survey Respondents – Add-on Measure Decision-Making Factors[1, 2]

(Multiple responses, base = partial installers only)

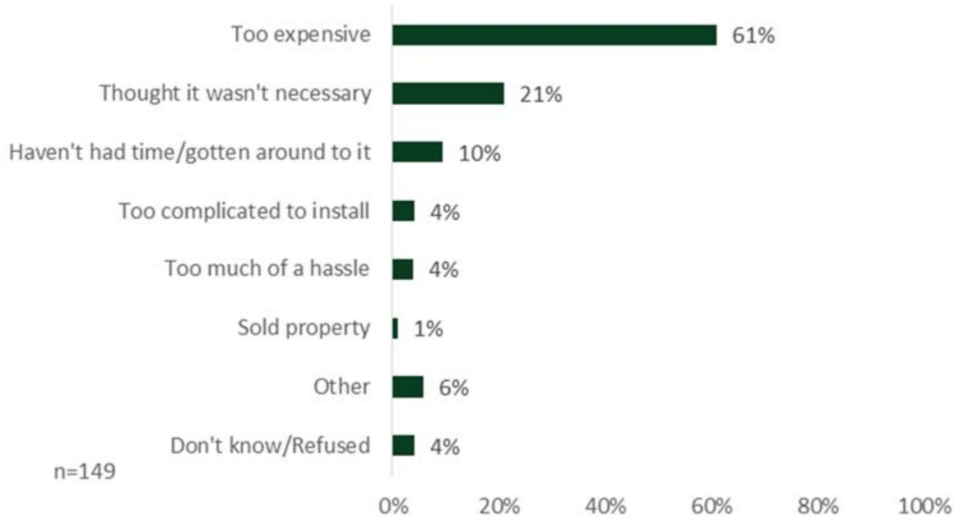
Improvement Selection Reasoning	Measure Type			Total (n=204)
	Core Only (n=65)	Other add-ons (n=68)	Insulation (n=71)	
Least expensive	40%	31%	34%	37%
Biggest energy/utility bill savers	28%	32%	41%	32%
Easiest to install	25%*	16%	10%	20%

Note: Percentages are weighted.
* Indicates that core-only respondents were significantly more likely to make decisions based on what was easiest to install than insulation respondents at the 90% confidence level.
[1] This table provides the most common response categories only. See Appendix A.3.1 for the full table.
[2] Respondents to this question are considered "partial installers" (those who have installed only some of the recommended measures).

As illustrated in Figure 22, over three-fifths of "non-installers" (those who have not installed any of the additional vendor-recommended improvements; 61%) who did not make any additional improvements recommended by the vendor explained that they had not done so because the improvements were too expensive. Some also did not make the improvements because they did not think they were necessary (21%). Nearly one-half of those who did not make any additional improvements plan to install some (41%) or all (5%) of the improvements within the next year (illustrated in Appendix A.3.1).

Figure 22: HES End-user Participant Survey Respondents – Barriers to Making Additional Upgrades

(Multiple responses, base = non-installers only)



Note: Percentages are weighted.

HES respondents who installed *some* (partial installers) or *all* (full installers) of the vendor-recommended improvements were most often driven to make these improvements to save money on their energy bills (57%) and to save energy generally (32%). As shown in Table 24, those who installed core-only measures were significantly more likely (63%) to be motivated to save money on their energy bills, those who installed insulation were significantly more likely to also be driven by a desire to be "green" or help the environment (11%), and those who made other add-on improvements were significantly more likely than others to also report comfort as a motivator (16%).

Table 24: HES End-user Participant Survey Respondents – Motivations to Make Additional Improvements[1]

(Multiple responses, base = both partial installers and full installers)

Reasons for Making Improvements	Measure Type			Total (n=249)
	Core Only (n=81)	Other add-ons (n=74)	Insulation (n=94)	
Save money on energy bill	63%*	41%	49%	57%
Save energy	33%	33%	30%	32%
Comfort	6%*	16%**	1%	6%
Be "green" / help environment	1%	5%	11%***	4%

Note: Percentages are weighted.
* Indicates statistically significant difference from other add-on and insulation respondents at the 90% confidence level.
** Indicates statistically significant difference from insulation respondents at the 90% confidence level.
*** Indicates statistically significant difference from core-only respondents at the 90% confidence level.
[1] This table provides the most common response categories only. See Appendix A.3.1 for the full table.

3.1.2 Financing

➢ ***HES end-users have fairly high levels of financing awareness; short-term survey respondents more often recall financing recommendations provided to them by their contractor and are more aware of financing options in general, likely as a result of survey timing.***

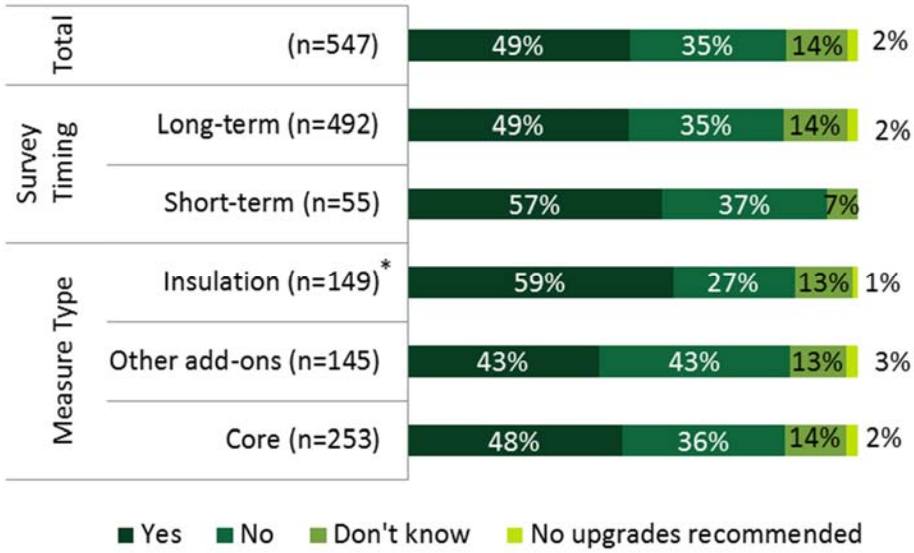
Slightly less than one-half of all HES respondents (49%) recalled that the vendor who completed the home energy assessment talked to them about program-related financing options, such as zero percent loans or on-bill repayments, to help with the financing of any of the additional improvements (Figure 23). Some interesting differences occurred across respondent types:

- **Survey timing.** Short-term survey respondents were somewhat more likely to recall being told about financing options (57%) than the long-term survey respondents (49%). This increased recall may be due to these respondents having participated more recently, perhaps because vendors are more consistently discussing options with participants (vendors do say they bring it up with almost every participant, as discussed below), or possibly due to the expansion of financing options offered and the efforts to promote them.

- **Measure type.** Similarly, when compared by measure type, HES respondents who had insulation installed were significantly more likely to recall being told about financing options (59%) than those who had only core measures installed (48%) or other add-on measures installed (43%), which may be attributed to the significant amount of financing with zero percent interest offered for insulation.

Figure 23: HES End-user Participant Survey Respondents – Whether or Not Financing was Recommended by Vendor

(Base = all HES respondents)

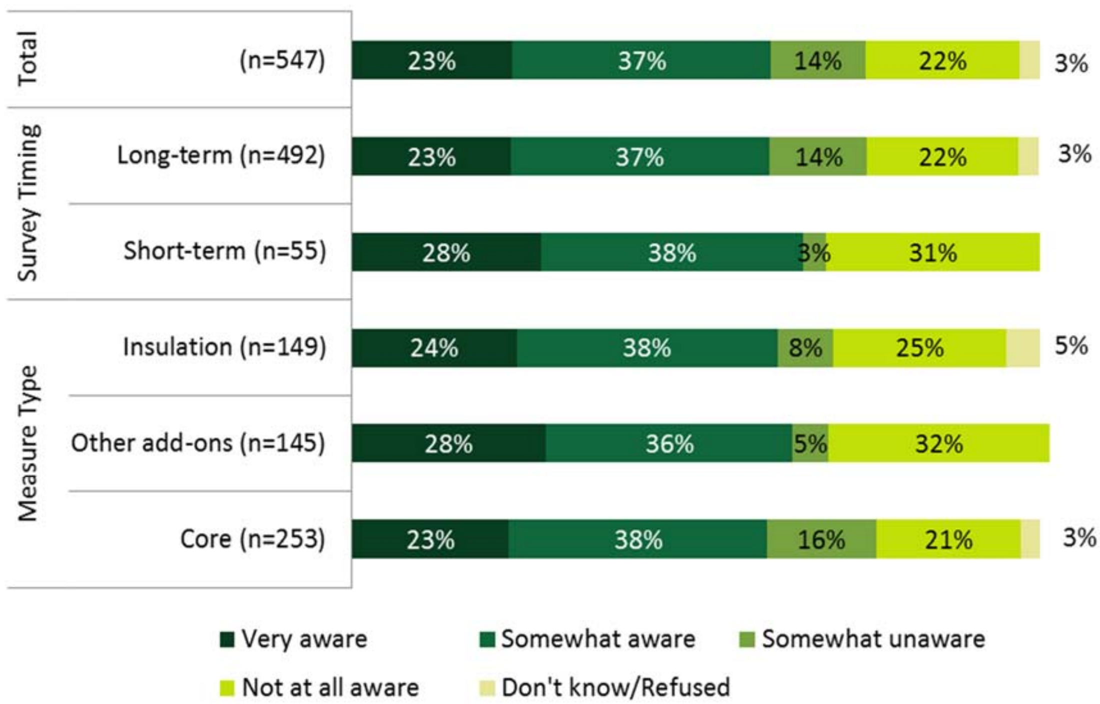


Note: Percentages are weighted.
* Indicates that respondents installing insulation were significantly more likely to be told about financing options than core-only and other add-on measure respondents at the 90% confidence level.

Three-fifths of all HES survey respondents (60%) were either somewhat aware or very aware of financing options—such as zero- or low-interest financing, on-bill financing, or other loan options—available to them through the program (Figure 24). Short-term survey respondents were more likely to be very aware or somewhat aware of program financing options (66%) than other survey respondents (60%).[74] This likely stems from the fact that they are more likely to recall the conversations with their vendor, as mentioned above.

Figure 24: HES End-user Participant Survey Respondents – Awareness of HES Financing Options

(Base = all HES respondents)



Note: Percentages are weighted.

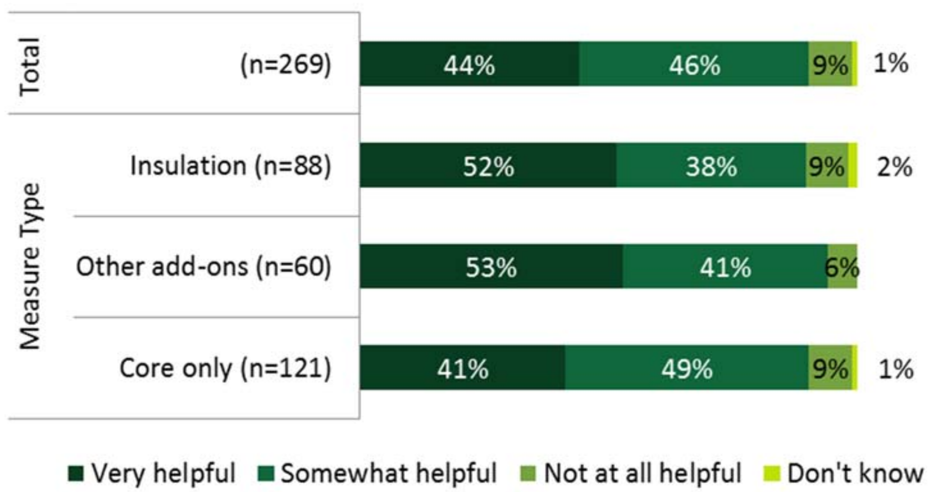
[74] There were no statistically significant differences between measure types or between survey time periods.

- ***HES end-users overwhelmingly found the program financing information that the vendors shared to be helpful.***

As shown in Figure 25, the vast majority of HES respondents whose vendor told them about program financing options (90%) found the information to be very helpful or somewhat helpful. When compared by measure type, a smaller percentage of core-only respondents found the information provided to be very helpful (41%) compared to those who installed insulation (52%) or other add-on measures (53%).[75]

Figure 25: HES End-user Participant Survey Respondents – Helpfulness of Vendor-Provided Financing Information

(Base = respondents with whom vendor discussed financing)



Note: Percentages are weighted.

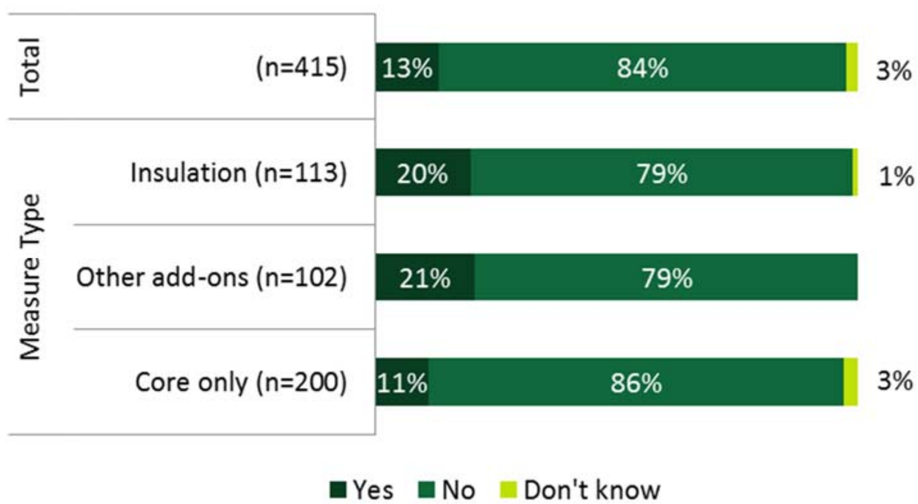
[75] Not a statistically significant difference.

- ***The few HES end-users who have or will use financing most often use the zero percent loans offered by the Connecticut Housing Investment Fund (CHIF) or the Energize Connecticut Heating Loan; the zero percent loan program is most attractive to non-users.***

As illustrated in Figure 26, only 13% of respondents who are aware of program financing opportunities have or plan to use these options. When compared by measure type, core-only installers were less likely to have used or plan to use financing for upgrades (11%) than those who installed insulation (20%) or made other add-on improvements (21%). Respondents most commonly reported that they had or will use financing for insulation (51%) and heating equipment improvements (33%); Appendix A.3.1 illustrates the full list of measures for which they had or will use financing.

Figure 26: HES End-user Participant Survey Respondents – Have Used or Plan to Apply for Financing Options

(Base = HES respondents aware of financing)



Note: Percentages are weighted.

As shown in Table 25, the most common financing options that partial or full installers have plans to apply for or have already used to make energy improvements include the Residential Energy Efficiency Financing, which most respondents referred to simply as the zero percent loan or CHIF loan (35%). Others also named the Energize Connecticut heating loan (21%). When compared by measure type, those who installed insulation were more likely to choose zero percent payment plans (eight of 17) than those who installed other improvements.

Table 25: HES End-user Participant Survey Respondents – Financing Options Selected

(Multiple responses, base = partial or full installers using or planning to use financing)

Financing Options	Measure Type (Count of respondents)			Total (n=43)
	Core Only (n=14)	Other add-ons (n=12)	Insulation (n=17)	
Zero percent loans, CHIF, Residential Energy Efficiency Financing	4	5	8	35%
Energize Connecticut heating loan	2	3	3	21%
Smart-E loan	2	0	0	9%
Other	0	1	2	4%
Don't know/Refused	6	3	4	36%

Note: The measure type columns provide unweighted counts, and the total column provides weighted percentages. R31 survey participants were not asked this question because the survey was already in the field before the question was added to the R4 participant survey.

Close to one-half (48%) of non-installers speculated that they would be likely to select zero or low-interest financing if they were to decide to make the vendor-recommended improvements, and over two-fifths (44%) would not use any of the options available to them regardless.

- ***HES end-users often do not need financing programs because they already have sufficient funds.***

Having sufficient funds (44%) is the most commonly reported reason HES respondents who have installed all or some of the recommended improvements provided for not using program financing to make additional improvements (Table 26). Second most commonly, they were not interested in pursuing program financing because they did not want to incur debt (12%). When compared by measure type, fewer core-only installers (41%) than insulation (50%) or other add-on (51%) installers (50%) did not use the financing options because they already had sufficient funds.

Table 26: HES End-user Participant Survey Respondents – Reasons for Not Using Financing Options[1]

(Multiple responses, base = partial or full installers not applying for financing)

Reasons for Not Using Financing	Measure Type			Total (n=158)
	Core Only (n=61)	Other add-ons (n=41)	Insulation (n=56)	
Have sufficient funds	41%	51%	50%	44%
Do not want debt	10%	13%	16%	12%
Did not have enough for down payment anyhow	8%	6%	5%	7%
Did not want to make the improvements anyway	*18%*	*13%*	*7%*	*15%*

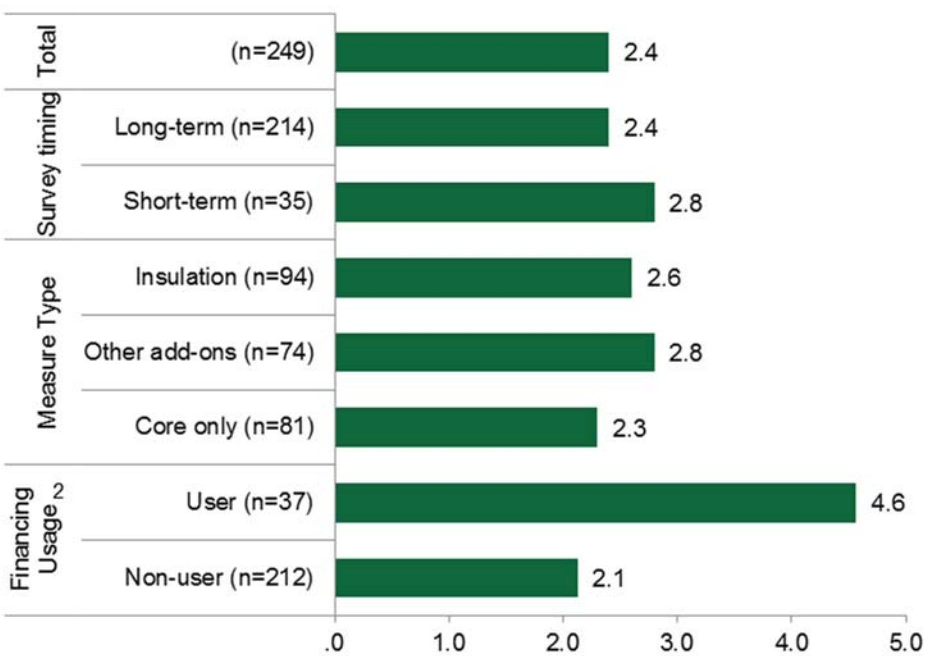
Note: Percentages are weighted.
[1] This table provides the most common response categories only. See Appendix A.3.1 for the full table.

- ***Program financing is not an important factor in HES end-users' decision to move forward.***

As depicted in Figure 27, using a 5-point scale, HES respondents who have installed all or some of the recommended improvements did not think that financing options were very important in their decision to install those improvements (mean of 2.4). When compared across time periods, those who had the assessment performed within the shorter term rated financing as somewhat more important (mean of 2.8) than those who had the survey conducted at a later time (mean of 2.4). Note that, given the small sample size of the short-term respondents, it is difficult to draw a statistically significant conclusion, but results are still likely to be indicative of the increase in importance that financing held in the program during the late 2014 and early 2015-time period. Not surprisingly, respondents that used some type of financing (4.6) gave a notably higher rating than those that did not use financing (2.1) (similarly, the small sample sizes make it difficult to draw a statistically significant conclusion).

Figure 27: HES End-user Participant Survey Respondents – Importance of Financing Options[1]

(Mean Rating, base = partial and full installers)



Note: Means are weighted.

[1] Rated on a scale from 1 to 5 where 1 equals "Not at all important" and 5 equals "Very important."

[2] Financing usage (user vs. non-user) indicates whether or not the respondent used financing to install any measures.

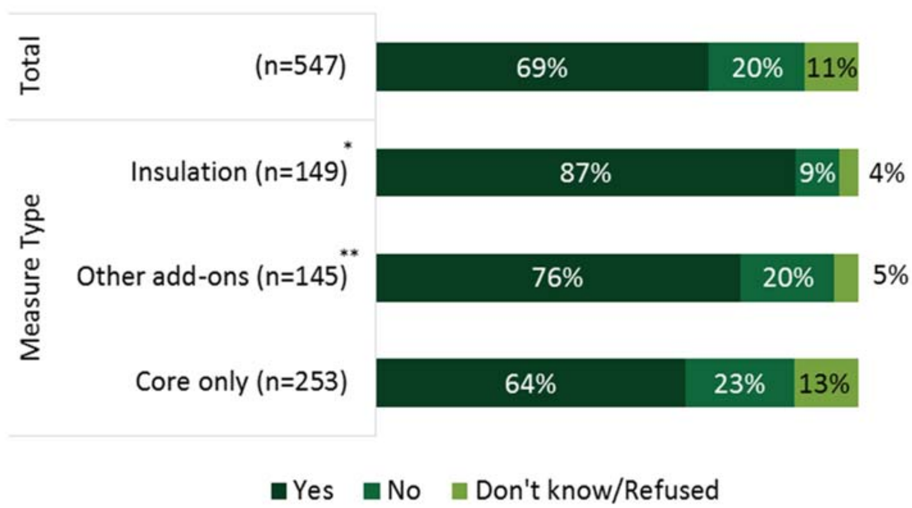
3.1.3 Rebates and Incentives

- ***Vendors tell the majority of HES end-users, especially insulation installers, about program rebate and incentive opportunities.***

As shown in Figure 28, more than three-fifths (69%) of all HES respondents recalled being told about rebate or incentive options by the vendor. When compared by measure type, those who installed insulation were significantly more likely to recall being told about rebates or incentives (87%) than other add-on (76%), or core-only respondents (64%). This difference is not surprising given that vendors have observed a great deal of enthusiasm among end-users about the size of insulation rebates (Section 3.5.2); it may mean that vendors are more often recommending them or that the size of the insulation rebates has more of a resounding impact on participants' memories.

Figure 28: HES End-user Participant Survey Respondents – Whether Vendor Recommended Rebates and Incentives

(Base = all HES respondents)

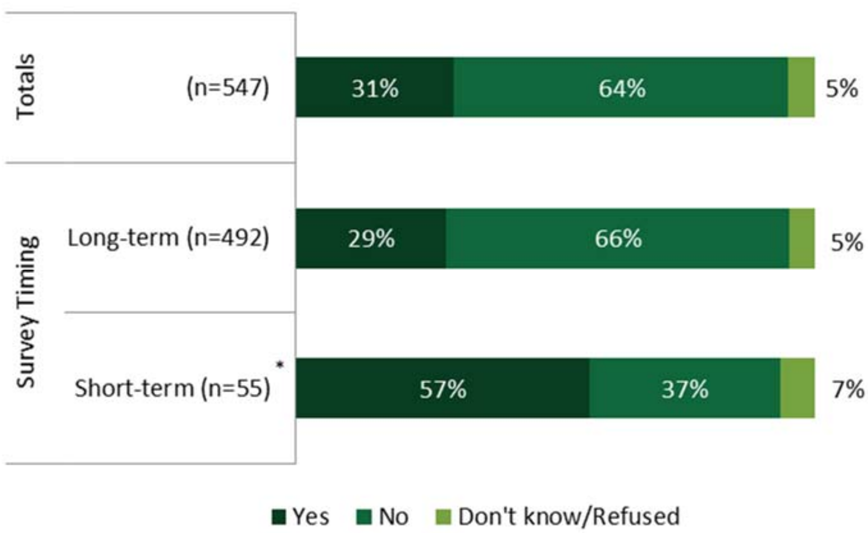


Note: Percentages are weighted.
* Indicates that respondents installing insulation were significantly more likely to have been told about rebates and incentives than core-only and other add-on measure respondents at the 90% confidence level.
** Indicates that respondents installing other add-on upgrades were significantly more likely to have been told about rebates and incentives than core-only respondents at the 90% confidence level.

Close to one-third of all HES respondents (31%) plan to use or have used rebates and incentives for the recommended improvements (Figure 29). Most often, they planned to use or have used them for insulation (53%) and heating equipment (19%; Appendix A.3.1). When compared by time period, short-term survey respondents were significantly more likely than long-term respondents to be planning to apply or to have applied for rebates or incentives (57% compared to 29%).

Figure 29: HES End-user Participant Survey Respondents – Have Used or Plan to Apply for Program Rebates or Incentives

(Base = all HES respondents)



Note: Percentages are weighted.
* Indicates that short-term respondents were significantly more likely than long-term respondents to have used or to have plans to use rebates and incentives at the 90% confidence level.

- ***Some HES end-users choose not to use rebates and incentives because they already have sufficient funds or, in contrast, the rebates are still not enough to help them cover down payments.***

As indicated in Table 27, the most common reason provided by HES respondents who have not or will not apply for rebates or incentives for the additional improvements is that they already have sufficient funds (15%). In contrast, the second most common reason provided is that they still would not have enough funds to pay for the down payment to make the upgrades (11%). When compared by time period, short-term survey respondents were more likely to report not needing the rebates or incentives (26%) than other respondents (14%). Long-term respondents were more likely to not want to make upgrades anyhow.

Table 27: HES End-user Participant Survey Respondents – Reasons for Not Using Program Rebates or Incentives[1]

(Multiple responses, base = HES respondents not using rebates or incentives)

Reasons for not Using Program Rebates or Incentives	Survey Timing		Totals (n=340)
	Short-term (n=25)	Long-term (n=315)	
Have sufficient funds	26%	14%	15%
Did not have enough for down payment anyhow	15%	11%	11%
Unaware of rebates	12%	10%	10%
Do want to make the improvements anyway	3%	21%	21%

Note: Percentages are weighted.

[1] This table provides the most common response categories only. See Appendix A.3.1 for the full table.

- ***HES end-users suggest that rebates and incentives would be most attractive if they covered close to one-half of the upgrade cost.***

Surveys asked HES respondents who either did not install any of the recommended improvements or installed only some of the recommended improvements how much of the cost of improvements they would need to be covered by program rebates and incentives to be enticed to move forward with all of the recommended improvements (Table 28). On average, they estimated that they would need close to one-half (48%). When compared by time period, short-term respondents were less likely to want all of the cost covered (8%) than other respondents (16%).[76]

Table 28: HES End-user Participant Survey Respondents – Portion of the Cost Needed to Encourage Improvements

(Base = non-installers and partial installers)

Portion of Cost Desired to Install All Recommended Measures	Survey Timing		Totals (n=347)
	Short-term (n=33)	Long-term (n=314)	
Percentage of Respondents			
All of the cost	8%	16%	16%
76-99% of cost	0%	6%	6%
51-75% of cost	0%	5%	5%
26-50% of cost	58%	43%	44%
1-25% of cost	33%	17%	18%
None	0%	13%	12%
Vendor did not make recommendations	5%	3%	3%
Would not move forward regardless of rebates	16%	12%	12%
Don't know/Refused	16%	26%	26%
Respondents' Value Estimates			
Average	45%	48%	48%
Median	50%	50%	50%

Note: Percentages are weighted.

[76] Not a statistically significant difference.

3.1.4 Financing Compared to Rebates and Incentives

- ***The combination of the availability of the program rebates and incentives with the availability of financing options is a motivating factor for those who use both of these incentive types.***

As shown in Table 29, the availability of the program rebates and incentives *in combination with* the availability of program financing options motivated close to three-fourths (73%) of HES respondents who have already applied or plan to apply for both program financing and incentives to move forward with the work. Among this small subset of the program participants, the availability of financing options alone motivated 15%, and rebates and incentives alone motivated 13%. Similar motivations are seen when compared by measure type installed. Importantly, though, this subset of the participants differs from most other participants who either choose not to adopt deeper measures or do so using rebates and not financing (e.g., compare the results in Figure 26 and Figure 29).

Table 29: HES End-user Participant Survey Respondents – Motivations for Moving Forward with Improvements

(Base = HES respondents who have applied or plan to apply for financing or rebates/incentives)

Motivations	Measure Type (Count of respondents)			Total (n=40)
	Core Only (n=14)	Other add-ons (n=13)	Insulation (n=13)	
The availability of program rebates and incentives was very important	1	1	3	13%
The availability of program financing options was very important	2	3	1	15%
The availability of rebates and incentives IN COMBINATION WITH the availability of financing options was very important	11	9	9	73%

Note: The table provides unweighted estimates given the small number of respondents. Also note that the measure type columns provide unweighted counts, and the total column provides weighted percentages.

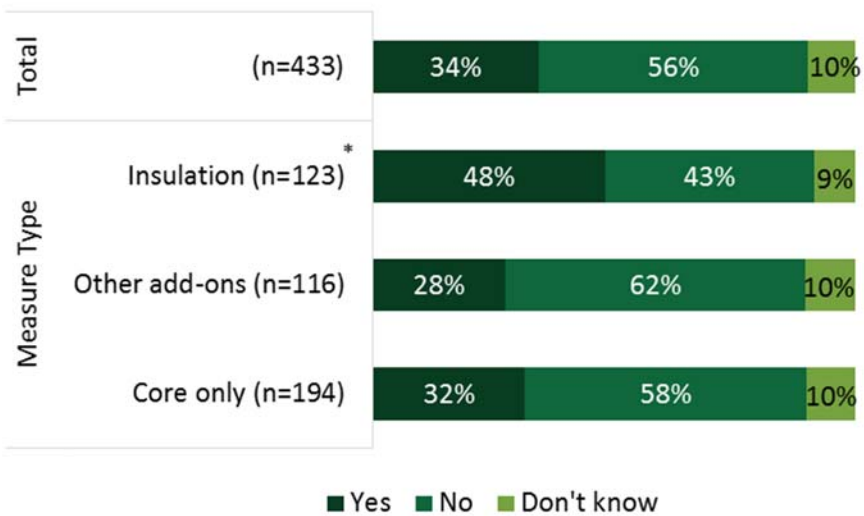
3.1.5 Impact of Vendor Follow-up

- ***Only some end-users report that vendors followed up with them after the assessment, but respondents do not view this as a critical factor; follow-up, however, is linked with the installation of insulation.***

Overall, slightly more than one-third of HES end-users (34%) recalled that their vendor followed up with them after the assessment (Figure 30).[77] When compared by measure type, those who had insulation installed (48%) were significantly more likely to recall vendor follow-up than those who installed core-only improvements (32%) or other add-on improvements (28%). This difference shows the importance of follow-up in encouraging end-users to adopt deeper-saving measures, with insulation being the deepest of them all. Using a scale of 1 to 5 where 1 means "not at all likely" and 5 means "very likely," respondents who did not receive follow-up contact rated their likelihood of moving forward with additional upgrades if they had received such a call as 2.1, on average (illustrated in Appendix A.3.1).

Figure 30: HES End-user Participant Survey Respondents – Vendor Follow-Up

(Base = HES respondents; R4 only)



Note: Percentages are weighted.
*Indicates that those who installed insulation were significantly more likely to have been followed up with by the vendor as core-only and other add-on measure respondents at the 90% confidence level.

[77] This type of outreach could include the vendor following up with the homeowner to solicit them to install add-on measures that they themselves perform in addition to energy assessments.

3.2 End-User Nonparticipant Surveys – Decision Making and Financing

The CATI surveys asked customers that did not participate in HES or HES-IE to assess their decision making regarding program upgrades they may have considered if they had participated in the program. The surveys also explored hypothetical decision making about program financing and rebate and incentive selections and the general importance of financing and rebates. Nonparticipants generally fell into one of several categories that determined which questions they would be asked, depending on whether or not they made energy efficiency improvements within the last year, if they were aware of program financing opportunities, and if they were aware of program rebates. Because their circumstances widely varied, their attitudes and perspectives, to some extent, conflicted with each other. Moreover, because they had not participated in the program, their responses about the hypothetical influence of rebates and financing on measure adoption must be considered in light of the actual behavior of participants.

3.2.1 Energy Efficiency Improvements Activity

- ***Nonparticipants who installed energy-efficiency measures on their own differed demographically from those who did not.***

The majority of nonparticipants had made energy efficiency improvements within the last year, with 68% of NLI respondents having done so and 60% of low-income respondents having done so. However, it should be noted that light bulbs, which may have been supported by upstream programs, were the most commonly mentioned upgrade (more details in Appendix A.3.2). Table 30 compares the demographics among those that made installation (installers) with those that did not (non-installers). Installers had significantly higher levels of educational attainment: 71% of installers had associates' or higher degrees while only 58% of non-installers had as high of education levels. There were other noticeable, but not statistically significant, differences between the two types of respondents: installers were more likely to have higher incomes, own their own homes, and be somewhat older than non-installers.

Table 30: End-user Nonparticipant Survey Respondents – Installation Completions by Select Demographics

(Base = all nonparticipants)

Demographic Category	% of Respondents within Installation Status Representing the Demographic Characteristic	
	Non-Installers (n=86)	Installers (n=154)
Income Category		
Low-income	40%	32%
Non-low-income	60%	68%
Educational Attainment		
Less than an associates' degree	42%*	29%
Associates' degree or more	58%	71%*
Home Tenure		
Owner	83%	90%
Renter	17%	10%
Age		
18 to 44	38%	30%
45 or older	62%	70%

* Indicates a significant difference between installer and non-installer respondents at the 90% confidence level.
Note: Percentages are weighted. Don't know and Refused responses are excluded; as such, sample sizes vary.

3.2.2 Motivations, Barriers, and Plans to Make Improvements

- ***Many nonparticipants making improvements chose them based on which ones would save the most on energy bills.***

As shown in Table 31**Error! Reference source not found.**, saving money on energy bills was one of the most common reasons both NLI nonparticipant (31%) and low-income nonparticipant (42%) installers had for making the energy-saving improvements that they did. Saving energy was also a common reason why both NLI nonparticipants (29%) and low-income nonparticipants (39%) made improvements, as was, needing to replace aging or broken equipment (31% and 21%, respectively). While nonparticipant installers resembled participant installers of add-on measures in their desire to save energy and money, nonparticipants were far more likely to say they were replacing aging or broken equipment, meaning that the nonparticipants did not take advantage of all bill and energy savings they could have had they replaced the equipment earlier. This "early replacement" approach is what at least some participants do once they learn about program rebates and financing.

Table 31: End-user Nonparticipant Survey Respondents – Reasons for Making Improvements

(Multiple responses, base = non-participant installers)

Reasons for Making Improvements	Non-Low-Income (n=95)	Low-Income (n=59)
Save money on energy bill	31%	42%
Save energy	29%	39%
Needed to replace aging/broken equipment	31%	21%
Health and safety	11%*	1%
Improve comfort	4%	6%
Be "green"/help environment	4%	3%
Wanted to make home improvements	2%	0%
Tax write-off	1%	0%
New home	1%	0%
Other	3%	4%
Don't know/Refused	1%	0%

*Indicates that NLI respondents are significantly more likely than low-income respondents to provide this response at the 90% confidence level.
Note: Percentages are weighted.

When asked to explain how they selected which improvements to install, the responses of nonparticipant installers aligned closely with their reasons for making improvements in the first place. Close to one-fourth (24%) of all program nonparticipants who installed energy effiiency improvements chose improvements that would save them the most on their energy bills. As shown in Table 32, NLI nonparticipants also cited the need to replace old or broken equipment (24%); low-income nonparticipants were equally as likely to make improvement selections based on affordability (21%) as they were to make their selections based on what would save them the most on their energy bills (21%).

Table 32: End-user Nonparticipant Survey Respondents – Reasons for Selecting Improvements Made[1]

(Multiple responses, base = nonparticipant installers)

Reason for Choosing Improvements	Non-Low-Income (n=95)	Low-Income (n=59)
Greatest energy/utility bill savings	26%	21%
Replace aging/broken equipment	24%	18%
Most affordable	16%	21%
Easiest to find	8%	9%
Research/comparison shopping	8%	8%
Easy installation	7%	9%
Contractor/vendor recommendation	9%*	0%

Note: Percentages are weighted.
* Indicates statistically significant difference from low-income category at the 90% confidence level.
[1] This table provides the most common response categories only. See Appendix A.3.2 for the full table.

- ***Program nonparticipant non-installers believe that energy-efficiency improvements are unnecessary; most of them have no plans to make any other improvements in the next year.***

As indicated in Table 33, the most common reason why program nonparticipant non-installers had not made energy efficiency improvements to their homes in the last year was that they think they are unncessary (41%). Low-income nonparticipants (37%) were significantly more likely than NLI nonparticipants (14%) to cite the cost of the improvements as a reason for not making them.

Table 33: End-user Nonparticipant Survey Respondents – Reasons for Not Making Improvements

(Multiple responses, base = nonparticipant non-installers)

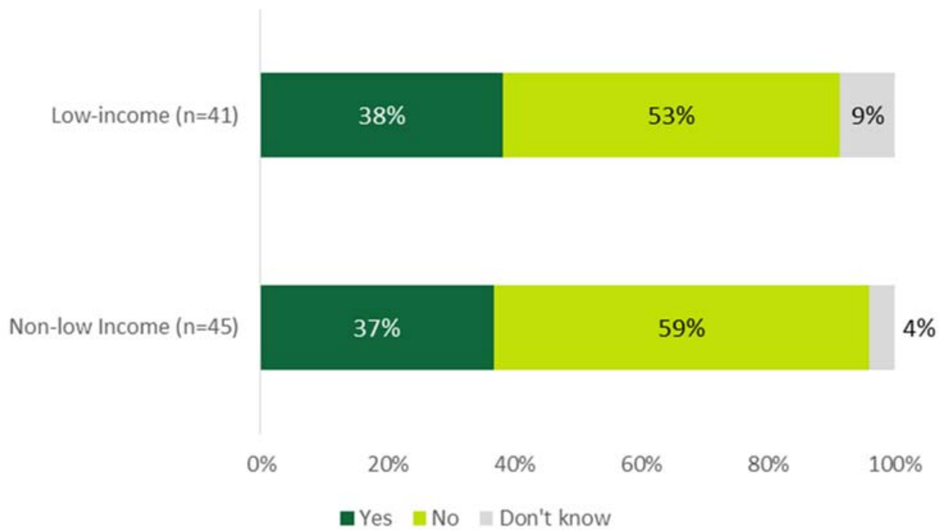
Reason for Inaction	Non-Low-Income (n=45)	Low-Income (n=41)
Deemed unnecessary	44%	39%
Too expensive	14%	37%*
Lack of time	17%	14%
Home is efficient enough	10%	2%
Renting home	3%	4%
Planning to move	2%	5%
Installation too complicated	2%	4%
Too much of a hassle	2%	4%
Missed deadline	0%	5%
Other	7%	7%
Don't know/Refused	10%	4%

Note: Percentages are weighted.
*Indicates that low-income respondents were significantly more likely than NLI respondents to provide this response at the 90% confidence level.

Close to three-fifths (57%) of nonparticipant non-installers do not plan to make any energy efficiency improvements to their homes in the next year (Figure 31). Similar results occured by income, with 59% of NLI nonparticipants and 53% of low-income nonparticipants not intending to make improvements.

Figure 31: End-user Nonparticipant Survey Respondents – Likelihood to Install Energy Efficiency Improvements in the Next Year

(Base = nonparticipant non-installers)



Note: Percentages are weighted.

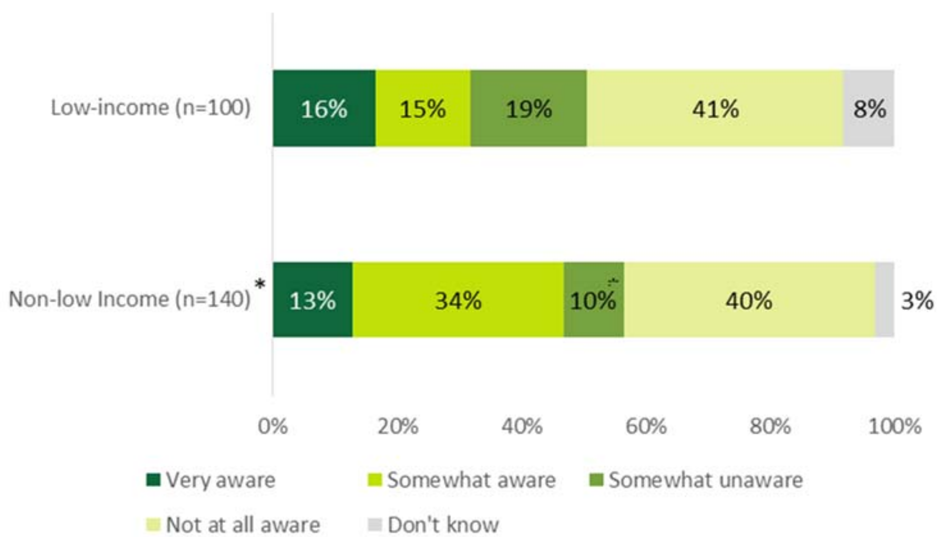
3.2.3 Awareness of and Attitudes toward Program Financing

- ***Nonparticipant awareness of program financing is relatively high; they did not apply because they had sufficient funds or—on the other end of the spectrum—because it would not have been enough money anyway.***

Overall, two-fifths (41%) of all program nonparticipants were somewhat aware or very aware of options to help them pay for improvements such as zero- or low-interest financing, on-bill financing, or other loan options that the program offers (Figure 32). Awareness was relatively high among nonparticipants when compared to a similar program in New York (Section 3.6). NLI nonparticipants were significantly more likely to have high awareness[78] (47%) of financing options than low-income nonparticipants (31%).

Figure 32: End-user Nonparticipant Survey Respondents – Awareness of Program Financing Options

(Base = all nonparticipants)



* Indicates that NLI respondents were significantly more likely to have high awareness (very or somewhat aware) of financing options than low-income respondents at the 90% confidence level.
Note: Percentages are weighted.

78 High awareness represents respondents that said that they were very aware or somewhat aware; low or no awareness represents respondents that said that they were somewhat unaware or not at all aware.

As shown in Table 34, regardless of whether they were installers or non-installers, NLI nonparticipants with **high** awareness of program financing options most commonly did not apply for financing because they had sufficient funds (17%). In contrast, other nonparticipants with **high** awareness of financing were nearly as likely to say that they did not apply for financing because they still would not have had enough money to install the measures (15%). Low-income nonparticipants who had **high** awareness of program financing options most commonly did not apply for financing because they would *not* have had enough money anyhow (23%). Additionally, they cited concerns about not having enough for the down payment (14%) and not wanting to incur debt (10%).

Table 34: End-user Nonparticipant Survey Respondents – Reasons for Not Applying for Financing[1]

(Multiple responses, base = nonparticipants with high awareness of financing)

Reason for Not Applying for Financing	Non-Low-Income (n=65)	Low-Income (n=32)
Amount of money not sufficient	15%	23%
Not necessary*	17%	8%
Did not want debt	13%	10%
Could not cover down payment[2]	5%	14%
Did not want to make improvements	5%	10%
Just learning about program now	5%	6%
Have not had time	6%	5%

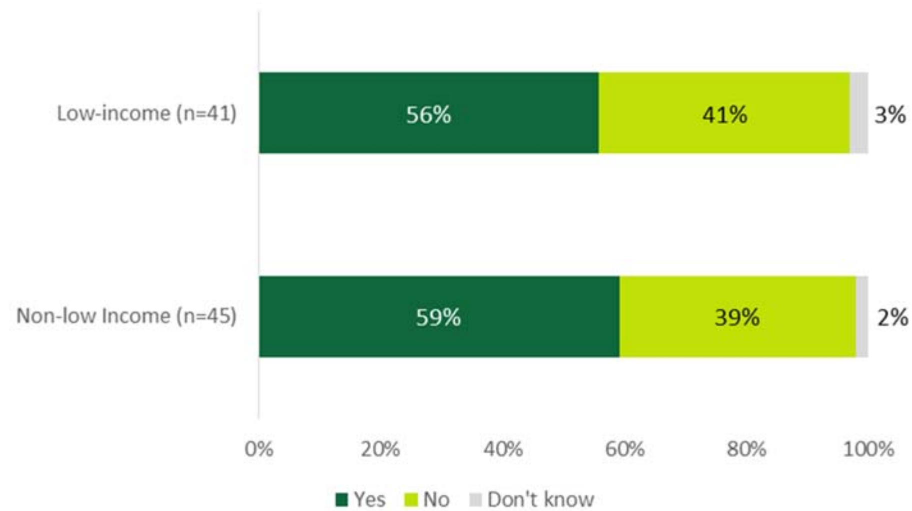
[1] This table provides the most common response categories only. See Appendix A.3.1 for the full table.
[2] Note that the direction of differences is as expected between the NLI and low-income respondent groups.
Note: Percentages are weighted.

- ***Many nonparticipants say they would have considered making improvements and applied for financing if they had known about financing.***

Close to three-fifths (58%) of all nonparticipant non-installers said they would reconsider moving forward with energy-saving improvements if they knew more about financing opportunities (Figure 33). Yet, it should be kept in mind that only 13% of HES participants reported actually using financing, so it is likely that nonparticipants may be providing an overly optimistic or socially desirable response of their likelihood to pursue measures with financing. When faced with the actual decision, they may not have pursued financing.

Figure 33: End-user Nonparticipant Survey Respondents – Willingness to Make Improvements if Knew about Financing

(Base = nonparticipant non-installers)

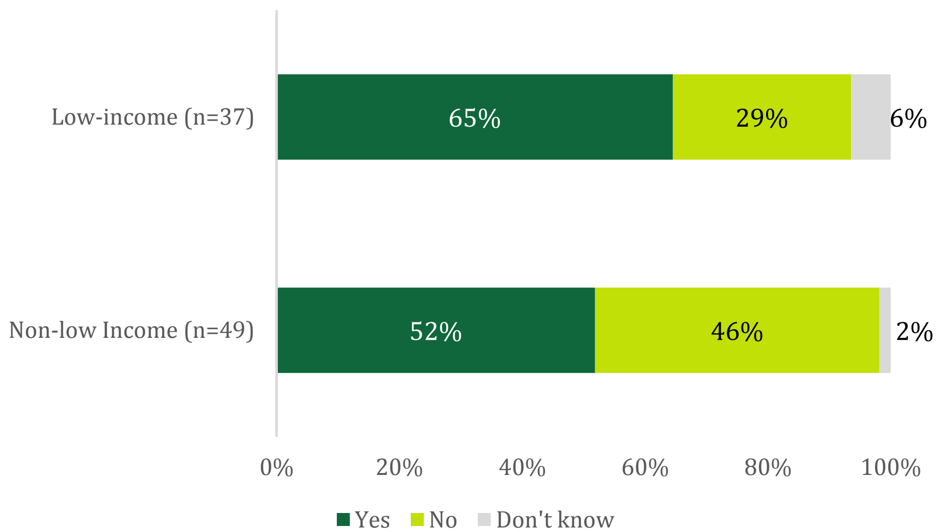


Note: Percentages are weighted.

Close to three-fifths (56%) of nonparticipant installers who had **low** awareness of program financing options said they would have been likely to apply for financing if they had known more about it (Figure 34). Similar to the non-installers, this estimate might be higher than in reality as respondents may have been providing an overly optimistic or socially desirable response. Low-income nonparticipants with **low** financing awareness were somewhat more likely to respond that they would have been likely to pursue financing (65%). Unlike NLI households, low-income households likely have less disposable income to spend on upgrades, so they may find financing options to be an appealing alternative compared to not completing the work at all.

Figure 34: End-user Nonparticipant Survey Respondents – Likelihood to Apply for Financing if Aware

(Base = nonparticipant installers with low financing awareness)



Note: Percentages are weighted. Sample consists of those who had made installations.

Very few nonparticipants installers had used any financing options (meaning those external to the programs) to help with the expense of those improvements (8% used financing overall; further details in Appendix A.3.2).

3.2.4 Awareness of and Attitudes toward Program Rebates and Incentives

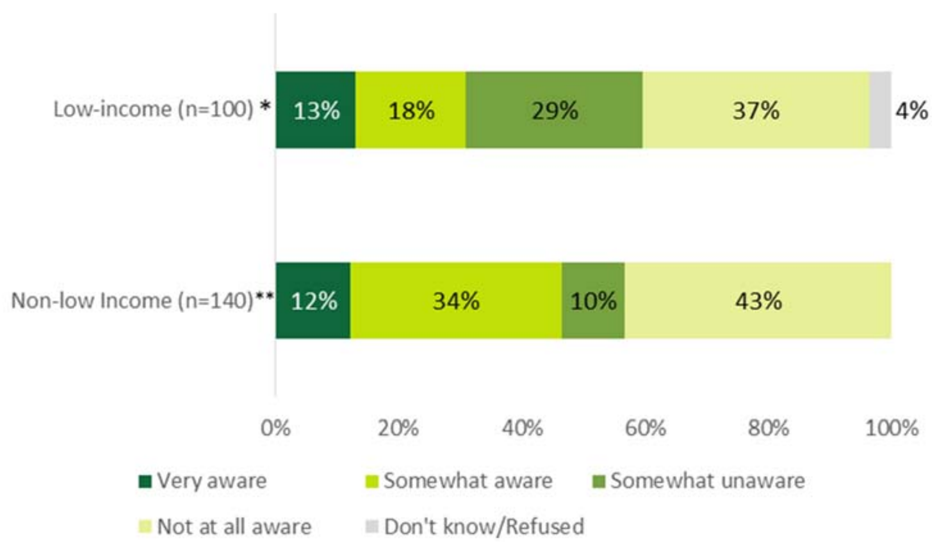
➢ ***Nonparticipant awareness of rebates is high, but usage of rebates is low.***

Just over two-fifths of all nonparticipants (41%) voiced high levels of awareness[79] of the rebates and incentives that the program offers to help people pay for energy efficiency improvements in their homes (Figure 35). There were significant differences in demographics between nonparticipants with high awareness of program rebates and incentives and those with low awareness of program rebates and incentives (Table 35): Specifically, among low-income respondents, a greater portion voiced statistically lower levels of awareness with rebates (41% vs. 27%), while among NLI respondents, a greater proportion cited statistically high levels of awareness with rebates (73% vs. 59%). Educational attainment displayed similar statistically significant patterns.

As illustrated in Appendix A.3.2, the vast majority of low-income nonparticipants (82%) and NLI nonparticipants (72%) did not use rebates to make energy-saving improvements; this is not surprising given that most program rebates require participation in HES.[80]

Figure 35: End-user Nonparticipant Survey Respondents – Awareness of Program Rebates and Incentives

(Base = all nonparticipants)



*Indicates that low-income respondents were significantly more likely to be somewhat unaware of program rebates and incentives than NLI respondents at the 90% confidence level.
**Indicates that NLI respondents were significantly more likely to be somewhat aware of program rebates and incentives than low-income respondents at the 90% confidence level.
Note: Percentages are weighted.

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[79] High awareness represents respondents that said that they were very aware or somewhat aware; low awareness represents respondents that said that they were somewhat unaware or not at all aware.
[80] Nonparticipants using utility rebates and incentives to make improvements were participants in a CEEF program, but not HES or HES-IE participants.

Table 35: End-user Nonparticipant Survey Respondents – Awareness of Program Rebates and Incentives by Select Demographics

(Base = nonparticipants able to identify awareness level)

Demographic Category	% of Respondents within Awareness Level Representing the Demographic Characteristic	
	Low or No Awareness (not at all aware or somewhat unaware) (n=145)	High Awareness (somewhat aware or very aware) (n=94)
Income Category		
Low-income	41%*	27%
Non-low-income	59%	73%*
Educational Attainment		
Less than an associates' degree	39%*	26%
Associates' degree or more	61%	74%*
Home Tenure		
Owner	86%	89%
Renter	14%	11%
Age		
18 to 44	36%	28%
45 or older	64%	72%

* Indicates a significant difference between low awareness and high awareness categories at the 90% confidence level.
Note: Percentages are weighted. Don't know or Refused responses are excluded; as such, sample sizes vary. Additionally, the table excludes one respondent that refused to provide a level of awareness.

- ***Despite relatively high levels of awareness of program rebates, nonparticipants that made improvements were held back from using rebates because they did not know enough about the incentives.***

Twenty-nine nonparticipant NLI respondents had installed measures and had high awareness of program rebates; the top reason why they did not use rebates was that the installers were not *as* aware of them as they thought that they needed to be (8 of 29) (Table 36). This group also commonly mentioned that rebates were unnecessary for them to make the improvements (6), which likely reflects their greater income. Due to small sample sizes, it is unclear what the most common reasons low-income nonparticipants had for not using the rebates (n=11).

Table 36: End-user Nonparticipant Survey Respondents – Reasons for Not Using Program Rebates

(Multiple responses, base = installers with high awareness of program rebates)

Reason for Not Using Program Rebates	Non-Low-Income (n=29)	Low-Income (n=11)
Low rebate awareness	8	1
Rebate was unnecessary	6	0
Did not want to make improvements	2	0
Too much of a hassle	2	1
Upgrade not covered by the program	3	2
Rebate amount not sufficient	1	1
Cannot cover down payment	1	0
Have not had time	1	0
Forgot about rebate	0	2
Rebate too confusing	0	1
Other	1	1
Don't know	4	2

Note: Unweighted counts are shown given the small number of responses.

3.2.5 Importance and Influence of Rebates, Incentives, and Financing

- ***Many of those nonparticipants that had been unaware of them hypothesized that program rebates and financing could have been influential if they had known more about them. Yet, nonparticipants that actually made installations placed little importance on program rebates and financing availability.***

Survey questions asked nonparticipants to rate the importance and influence levels of rebates and financing either hypothetically or in reality. Figure 36 illustrates respondents' mean ratings (and helps to clarify the base group of respondents that were asked about each element). Nonparticipant installers and those aware of program rebates and financing were less likely to recall placing importance on rebates and financing than those that were unaware and asked to postulate on the *potential* importance of them if they had known about them: Put another way, nonparticipants that learned about rebates and financing during the survey thought they sounded like a great idea, but nonparticipants who already had known about rebates and financing or had installed measures on their own did not find the offerings very motivating. Again, it is worth noting that relatively few program participants have actually used rebates and financing, which suggests that the enthusiasm of those just learning about the offerings may not be indicative of actual behavior.

- **Program rebates and incentives (hypothetically)**. The majority of installers and non-installers that had low or no awareness of program rebates (55%) hypothesized that the program rebates would have been influential[81] on their decisions to move forward with work if they had known about them.[82] Differences in mean ratings and distribution of ratings between installers and non-installers were negligible.
- **Rebates, incentives, and financing generally (in reality).** Nearly one-fifth of nonparticipant installers thought that the *general* availability of rebates (19%) was important[83] in their decision to move forward, and nearly one-quarter of them (24%) thought that that the *general* availability of financing was important. The average importance rating that low-income nonparticipant installers (2.8) gave to the level of influence of the general availability of financing was significantly higher than that of NLI nonparticipant installers (1.9). Thus, this subset of nonparticipant installers is essentially saying that knowing that rebates and financing existed motivated them to install energy-efficiency measures even though they did not take advantage of the offering. This is a form of nonparticipant spillover, which the study did not quantify but should be noted.
- **Program rebates, incentives, and financing (in reality).** Seventeen percent of nonparticipant installers that had low or high awareness of *program* rebates and/or financing thought that the combination of the two was influential on their decision to move forward with installing upgrades, with low-income nonparticipants significantly

[81] "Influential" signifies ratings of 4 or 5, where 1 equaled "no influence" and 5 equaled "a great deal of influence."
[82] Survey questions did not ask respondents to *rate* the potential influence of program financing opportunities if they had known about them.
[83] "Important" signifies ratings of 4 or 5, where 1 equaled "not at all important" and 5 equaled "very important."

more likely to attribute influence (2.7) than NLI nonparticipants (1.8). Again, this points to at least some level of nonparticipant spillover.

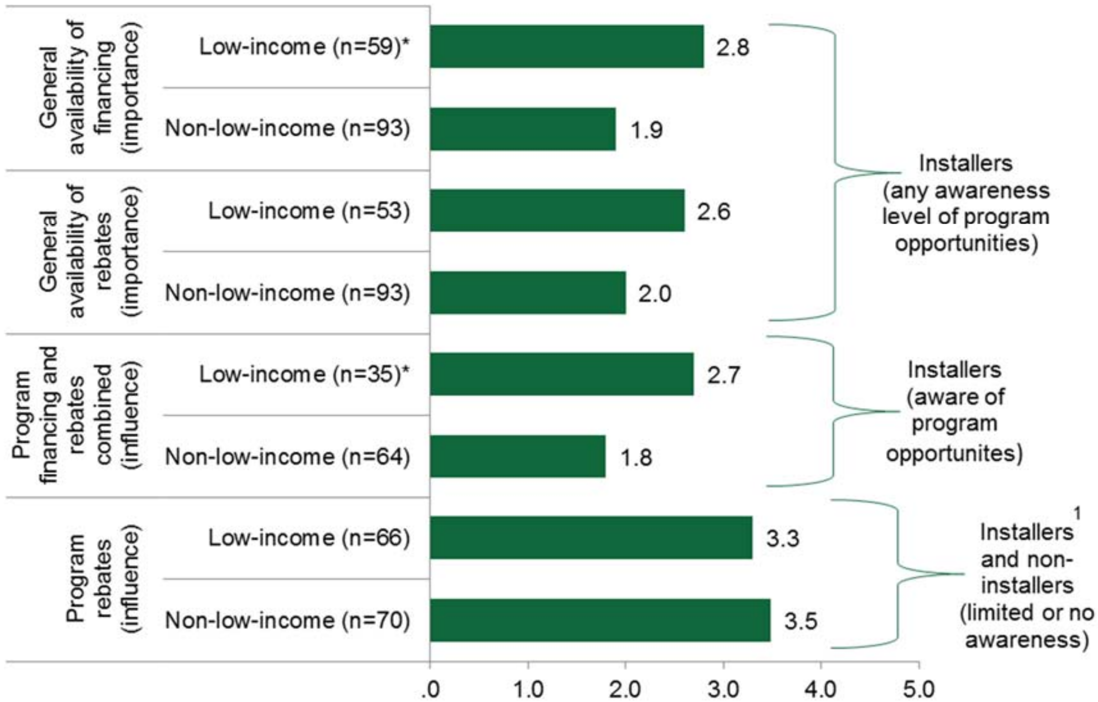
The differences between nonparticipants' attitudes towards their decision making hypothetically and in reality—when it came to the value of rebates and incentives—may result from the demographic differences between the installers and non-installers and those with high awareness and those with low or no awareness of program rebates; or it could be attributed to other social/psychological factors:

- **Relation to income category.** Those with low or no awareness of program rebates were more often low-income than those with high awareness of program rebates. This difference may indicate that that the low-income group may value or need to rely on rebates more greatly than those with higher incomes and, therefore, perceive that they would have greater levels of influence on their decision making.
- **Relation to other demographics.** Other demographic differences[84] associated with awareness of rebates and incentives and actions (installer vs. non-installer) may explain the difference in responses, as well. Respondents with lower levels of education or that are younger may not have access to the resources that might assist them in making decisions about financing a home improvement and, as a result, may have different perspectives towards making home improvements.
- **Respondent psychology.** The reader might also speculate that it is possible that respondents, whom were only *just* asked about installations and told about rebates and incentives, had not had adequate time to fully reflect on the implications or financing involved in making improvements—either because 1) they had not thought about making these improvements or 2) at all factored in the possibility of rebates. In other words, they may have been attracted to the idea abstractly but in reality may learn that the rebates could play a smaller role in their decision making than they anticipated.

[84] Demographic differences discussed previously in this sub-section indicated that the installers and the respondents with high awareness of program rebates had higher incomes, higher educational attainment, more often were homeowners, and were older than their counterparts.

Figure 36: End-user Nonparticipant Survey Respondents – Importance and Influence of Rebates, Incentives, and Financing in Decision Making

(Mean ratings, bases vary by question)



Note: Means are weighted. Depending on the question, interviewees rated either the importance or influence of each element on a scale of 1 to 5, where 1 equaled "not at all important" and 5 equaled "very important" or 1 equaled "no influence" and 5 equaled "a great deal of influence."
* Indicates that low-income respondents provided a significantly higher average rating than NLI respondents at the 90% confidence level.
[1] Ratings did not vary between installers and non-installers.

3.3 HES-IE Landlord and Property Manager Interviews – Decision Making and Financing

Sixteen HES-IE landlord and property manager interviewees who installed add-on measures received program incentives. One of them—the project installed refrigerators and additional lighting equipment—also received on-bill financing from the program.

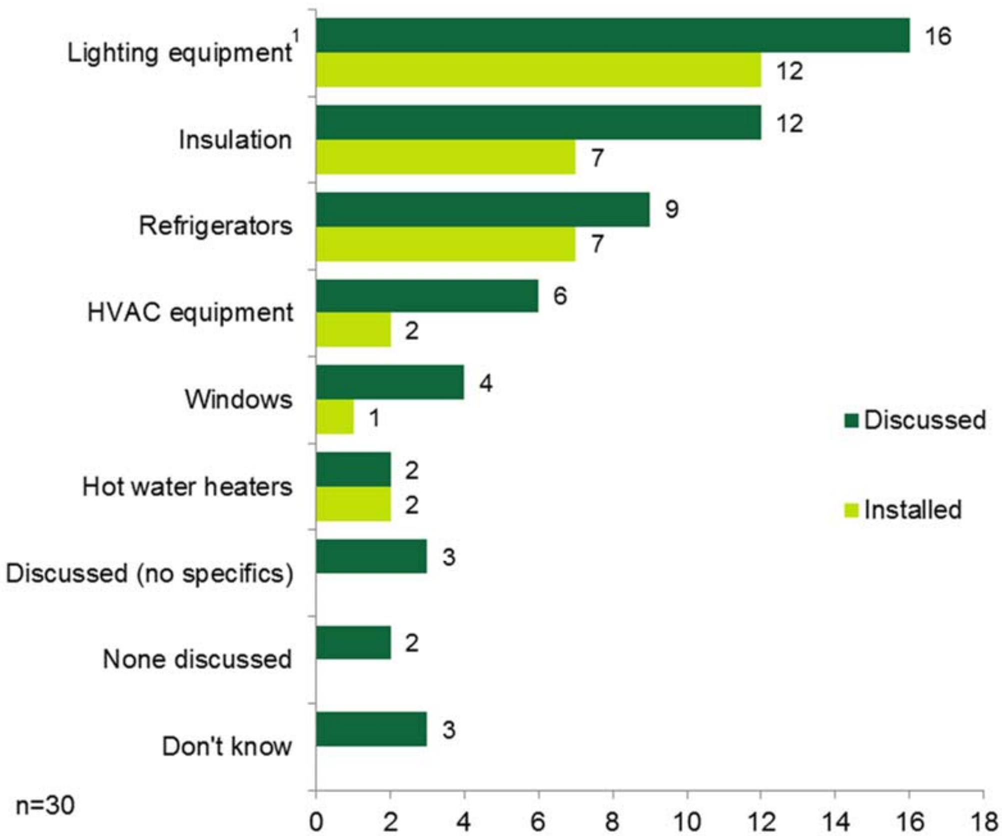
3.3.1 Measure Recommendations

- ***Landlords recall that vendors discuss lighting, insulation, and refrigerators most often.***

Most landlords and property managers (25 of 30) recalled their vendors discussing energy efficiency upgrades either during the assessment or after the assessment, recalling discussions around lighting equipment (16 of 30),[85] insulation (12), and refrigerators (9) as potential add-on measures. Comparing the number of measures that were installed to the number of measures discussed among this sample, it appears that hot water heaters, refrigerators, and insulation had the highest "rates of adoption" (Figure 37).[86]

Figure 37: HES-IE Landlord and Property Manager Interviewees – Measures Discussed During or After Assessment

(Count of projects)



[1] The "lighting equipment" category in this chart includes both core-service and add-on lighting measures (aside from light bulbs).

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[85] Interviewees often had a difficult time distinguishing the difference between the free core-service lighting equipment and the add-on lighting equipment in which they or their companies needed to invest. Interviewers did their best to help them differentiate, but the analysis cannot be certain of exactly which interviewees were recommended to invest further in lighting upgrades and exactly which of those moved forward with investing in the recommended lighting upgrades.

[86] The study does not formally consider these "adoption rates." To estimate a true adoption rate, the algorithm requires the number of recommended measures that participants installed as recorded in the program database. Given that program tracking data did not include measure recommendations, the analysis used interviewee recall as a proxy to suggest adoption. The small sample size does not support this as a statistically sound estimate.

3.3.2 Decision-making factors

➢ ***Landlords cite incentives, energy bill savings, and return on investment as pivotal factors in deciding to install measures.***

Landlords and property manager interviewees greatly value incentives in their decisions to install add-on measures. Using a scale of 1 to 5 where 1 means "not at all important" and 5 means "very important," HES-IE landlords and property managers rated the program incentives that they were offered a 4.9, on average, with only two of them rating it less than 5.0 (n=13).

"[The incentives] were everything."

– HES-IE property manager

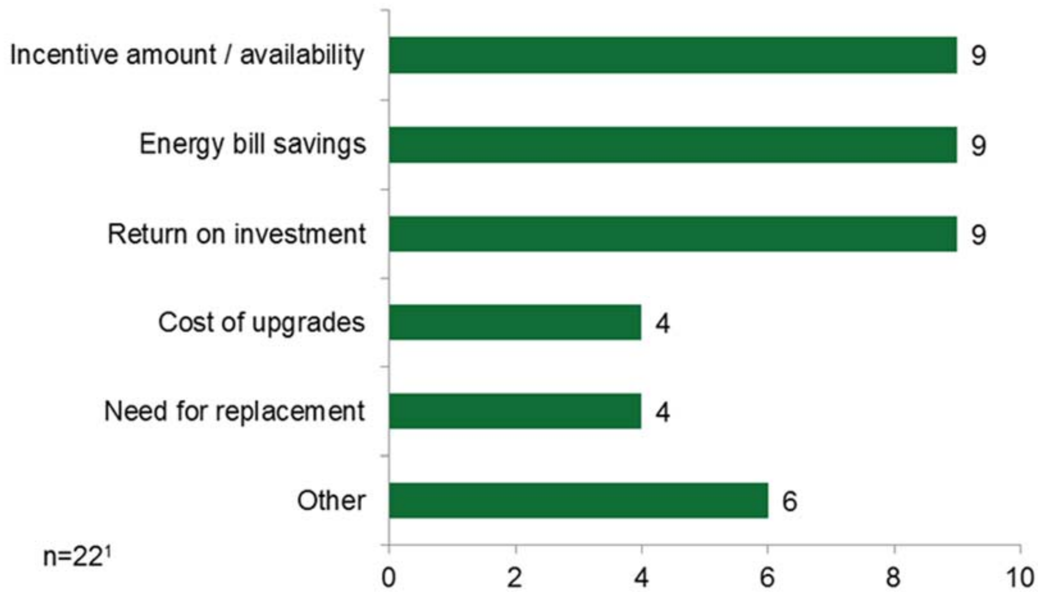
When asked to identify the factors involved in their processes of deciding which energy efficiency upgrades (both recommended and not recommended) to make, they pointed to incentives, as well as energy bill savings and return on investment (Figure 38):

- **Incentive availability.** Nine pointed to the availability of incentives. A couple interviewees said that the incentives simply made it clear that they should move forward with refrigerators, in particular, with one of them saying that the substantial incentive amount made them feel that "money didn't really enter into" the decision to purchase new refrigerators.
- **Energy bill savings**. Often referring to their own limited budgets, their concerns for their tenants' budgets, and recognizing the inefficiency of their existing equipment, nine interviewees specified that they made their decisions with the goal of decreasing energy bills.
- **Return on investment**. Nine interviewees said that the return on investment was a key input. For example, two of the interviewees considered payback as an important factor in their decisions to invest in energy-efficient lighting:

  If it was just a fixture, just a simple replacement, [we would estimate]: "Would we get it back in three years, five years, seven years, or ten years?" And then we tried to figure out if it was worthwhile investing the money.

Figure 38: HES-IE Landlord and Property Manager Interviewees – Add-on Measure Decision-Making Factors

(Multiple responses, count of responses)



[1] Eight interviewees did not respond to this question.

3.3.3 Financing Discussions and Preferences

- ***Long-term costs, lack of information, and lack of need detract from partaking in financing.***

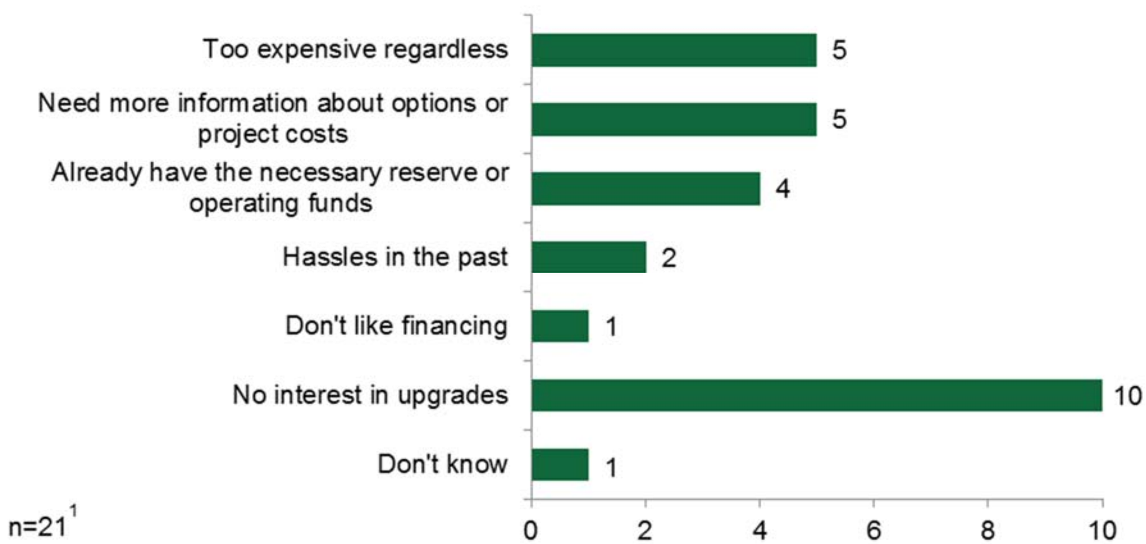
Fourteen of the landlords emphasized that they would not be interested in loans or financing opportunities to make additional energy-saving upgrades, explaining that the projects would be too expensive to implement despite financial support (five), there was not enough information available to them (five), or they already have the funds in their operating or reserve budgets (four).

> *[The vendor] may have brought it up, but it would not be anything that we were interested in at the time . . . Because if there is an interest rate attached to it—we had the cash on hand—[loans] just increase the cost to us [in the long term]. If it was low-interest financing, that might have been something we would have looked at. This was part of a longer construction project, so we were trying to package it up and handle it with slow-source financing.*

Ten interviewees said that they had no interest in making additional upgrades regardless of financial factors. Figure 39 illustrates the financing participation barriers that interviewees described.

Figure 39: HES-IE Landlord and Property Manager Interviewees – Financing Participation Barriers

(Multiple responses, count of responses)



[1] Nine interviewees did not respond to this question.

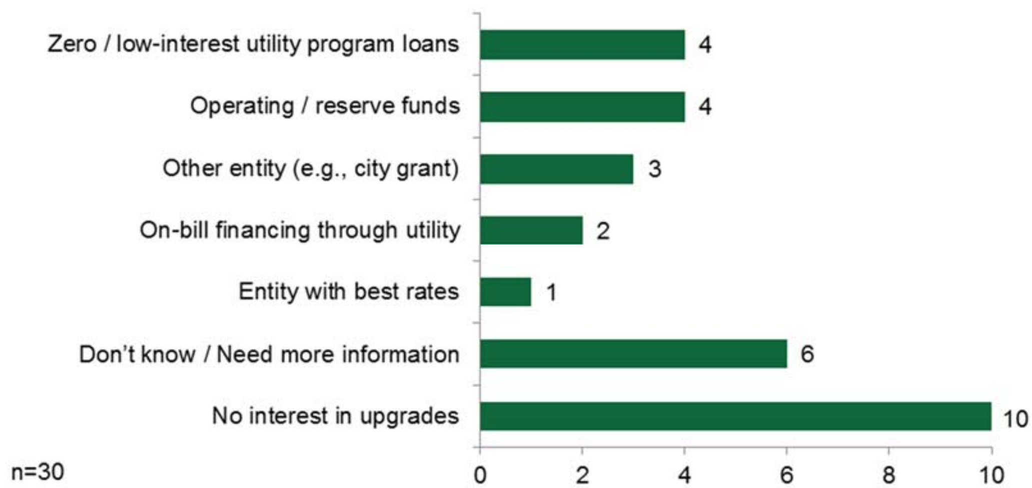
➢ ***Potential utility low-interest loans or on-bill financing are attractive to some landlords and property managers.***

When speculating what financing options they would use if they were to move forward with making additional energy efficiency upgrades, most often they said that they would use utility program loans or on-bill financing if available (6 of 20),[87] observing that the rates are "reasonable." Four of the interviewees said that they had enough "cash on hand" to pay for the upgrades out of their own operating or reserve funds and, as a result, would not need loans. Others needed more information about project costs and financing opportunities to make an educated decision (five). Figure 40 presents their responses in full.

> "We really don't do anything with financing, but if we did, we would go through the utility."
>
> *– HES-IE property manager*

Figure 40: HES-IE Landlord and Property Manager Interviewees – Financing Preferences

(Count of respondents)



3.4 End-User Data Analysis – Deeper-Measure Uptake

Using the Eversource[88] participation database (from July 2013 through April 2015) to assess deeper-measure uptake, the study estimated the percentage of core-services participants who, following the assessment, subsequently installed additional add-on measures both overall and by vendor.[89] The overall "deeper-measure uptake rate" at which core-services customers installed these additional measures was 21% among HES participants and 11% among HES-IE participants, although it should be remembered that adoption of deeper measures by HES-IE households is largely a reflection of which

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[87] On-bill financing is not currently offered to multifamily participants.
[88] The UI HES and HES-IE data did not include the vendor name variable necessary to conduct this analysis.
[89] The estimates exclude projects where a landlord or property manager was the point of entry into the program.

measures the program rules dictate they should receive for free. Add-on measures were most commonly insulation: about one-fifth of HES projects (15%) received insulation and insulation represented more than three-fifths of all HES add-on measures installed (62%).

Among HES projects, the rate of uptake across vendors ranged from 11% to 31% (Table 37). However, the comparison of rates between vendors does not account for demographic differences in customer bases or any other factors which may influence the uptake of add-on measures. Note also that the variation in the percentage of total projects for each vendor depends in part on where they operate in the state and their own ability to take on greater or fewer HES jobs from the Companies. It may also indicate the vendors' own marketing and outreach, as a company such as Next Step Living tends to promote itself more than some of the smaller, local vendors may.

Table 37: HES Projects Deeper-Measure Uptake, by Measure and Vendor

Vendor Name	HES Projects		% of Vendor's Projects with Add-on Measure[1]						
	Count of HES Projects	% of Total HES Projects	Heat Pumps	Heating Equipment	Insulation	AC Equipment	Hot Water Heaters	Windows	Any Add-on Measures
A Plus Installation, LLC	431	2%	2%	2%	9%	1%	<1%	1%	15%
Aiello Home Services	991	4%	4%	6%	9%	7%	1%	1%	22%
BCB Conservation Group, LLC	445	2%	2%	<1%	18%	2%	1%	9%	29%
Climate Partners, LLC	157	1%	1%	1%	15%	6%	1%	-	23%
Competitive Resources, Inc.	1,279	5%	2%	1%	21%	2%	1%	1%	26%
EcoSmart by R Pelton Builders, Inc.	1,959	8%	3%	2%	24%	4%	1%	1%	31%
Energy Efficiencies Solutions, LLC	1,602	7%	2%	1%	13%	2%	1%	12%	28%
Energy Resource Group	734	3%	4%	1%	13%	1%	1%	1%	19%
EnergyPRZ, LLC	1,459	6%	3%	<1%	19%	1%	<1%	2%	23%
Fox Heating Services, Inc.	323	1%	7%	-	10%	1%	<1%	4%	19%
Greenbuilt Connecticut	269	1%	3%	1%	21%	2%	1%	3%	26%
Gulick Building & Development, LLC	549	2%	1%	1%	8%	1%	1%	3%	13%
Handyman Express Energy Solutions LLC	426	2%	1%	2%	7%	2%	1%	1%	11%
Hoffman Fuel	198	1%	1%	1%	11%	2%	2%	1%	16%
Home Doctor of America	408	2%	6%	3%	17%	2%	2%	1%	26%
Lantern Energy, LLC	1,177	5%	4%	1%	14%	1%	1%	1%	19%
Molina & Associates, Inc.	280	1%	3%	-	11%	1%	1%	1%	15%
New England Conservation Services, LLC	1,113	5%	3%	1%	13%	2%	1%	1%	18%
New England Smart Energy Group, LLC	1,789	8%	3%	1%	14%	2%	1%	1%	19%
Next Step Living, Inc.	3,834	16%	4%	<1%	18%	1%	<1%	<1%	22%

Vendor Name	HES Projects		% of Vendor's Projects with Add-on Measure[1]						
	Count of HES Projects	% of Total HES Projects	Heat Pumps	Heating Equipment	Insulation	AC Equipment	Hot Water Heaters	Windows	Any Add-on Measures
R&W Heating, LLC	263	1%	5%	-	13%	-	<1%	2%	19%
Santa Fuel, Inc.	434	2%	1%	2%	14%	2%	1%	2%	19%
Tri City Home Energy Services	403	2%	2%	3%	5%	4%	1%	<1%	14%
Uplands Construction Group, LLC	409	2%	3%	<1%	20%	1%	1%	3%	24%
Victory Industries, LLC	1,467	6%	2%	1%	10%	3%	1%	2%	18%
Wesson Energy, Inc.	1,390	6%	2%	1%	12%	2%	1%	1%	16%
Other Vendors[2]	76	<1%	3%	-	11%	1%	-	-	12%
Total	**23,865**	**100%**	**3%**	**1%**	**15%**	**2%**	**1%**	**2%**	**21%**

Source: Eversource HES program database

[1] The table does not include a column devoted to measure types representing less than 3% of all add-on measures in the HES database. The "Any Add-on Measures" column includes all projects for which the vendor installed at least one add-on measure (regardless of the measure type or quantity of measures); the percentages in that column are not equal to the sum of the percentages in the other measure columns because individual households may have installed more than one measure type.

[2] Includes all HES vendors with fewer than 100 records

Table 38 shows for each core-services vendor the percentage of HES-IE core-services projects that subsequently installed additional add-on measures. The rate of additional measure uptake, 11%, is significantly lower than the rate for HES participants (21%). This difference is not surprising given that most of these deeper measures would have been provided for free to HES-IE households, and limited resources likely reduces the proportion of households that can receive deeper measures. Additionally, the list of approved add-on measures for HES-IE is smaller than for HES. Variations across vendors could reflect characteristics of the participants and their residences, program budgets, and the nature of the services provided by the vendor. To that last point, some of the vendors are CAAs while others serve only HES-IE or are brought in for specific projects or purposes. With some exceptions, the CAAs exhibit lower uptake rates than other vendors, and this likely reflects the different nature of these organizations and their role in the HES-IE program compared to the other vendors.

Together, insulation (53%) and refrigerators (40%) represented the vast majority of the HES-IE add-on measures in the database: 7% of HES-IE projects had insulation installed and 5% of them had refrigerators installed.

Table 38: HES-IE Projects – Deeper-Measure Uptake, by Measure and Vendor

Vendor Name	HES-IE Projects		% of Vendor's Projects with Add-on Measure[2]					
	Count of Projects	% of Total Projects	Heating Equipment	Insulation	Freezers	Refrigerators	Windows	Any Add-on Measures
ABCD[1]	1,076	4%	<1%	6%	1%	3%	<1%	8%
ACCESS[1]	2,840	10%	<1%	12%	<1%	5%	<1%	16%
CRT[1]	5,416	19%	<1%	9%	<1%	5%	<1%	13%
Competitive Resources, Inc.	3,351	12%	-	<1%	<1%	1%	-	1%
Energy Efficiencies Solutions, LLC	1,144	4%	<1%	1%	<1%	4%	<1%	5%
Energy Resource Group	614	2%	<1%	21%	2%	11%	1%	31%
HESHP	104	<1%	-	-	-	-	-	-
Handyman Express Energy Solutions LLC	1,185	4%	<1%	7%	1%	12%	1%	15%
Mr. Handyman of Upper Fairfield County	1,589	6%	<1%	16%	3%	14%	<1%	26%
New England Conservation Services, LLC	1,072	4%	<1%	18%	<1%	3%	1%	20%
New Opportunities, Inc. [1]	4,585	16%	<1%	6%	1%	9%	<1%	13%
Santa Fuel, Inc.	120	<1%	-	2%	-	-	-	2%
WRAP	4,988	18%	-	-	-	-	-	-
Wesson Energy, Inc.	311	1%	2%	10%	2%	14%	3%	22%
Other Vendors[3]	191	1%	-	35%	2%	7%	1%	38%
Total	**28,586**	**100%**	**<1%**	**7%**	**1%**	**5%**	**<1%**	**11%**

Source: Eversource HES-IE program database

[1] Denotes a CAA

[2] The table does not include a column devoted to measure types representing less than 1% of all add-on measures in the HES-IE database. The "Any Add-on Measures" column includes all projects for which the vendor installed at least one add-on measure (regardless of the measure type or quantity of measures); the percentages in that column are not equal to the sum of the percentages in the other measure columns because individual households may have installed more than one measure type.

[3] Includes all HES-IE vendors with fewer than 100 records

3.5 HES Vendor Interviews – Decision Making and Financing

While some HES participants know prior to having the assessment that rebates and financing options exist, the HES program relies on vendors to promote and explain these incentives to eligible participants. Given the importance of vendors in the rebate and financing process, the study queried 23 of the 24 vendors interviewed[90] as part of the joint R4/R46/R151/R157 effort about their promotion of rebates and financing and participant reactions to the two incentives.

3.5.1 Vendor Promotion of Rebates and Financing

➢ ***Vendors most often recommend CHIF loans, Smart-E Loans, and on-bill financing; among both the vendors and program materials, the financing nomenclatures used are inconsistent.***

The study asked vendors which rebates and financing opportunities they typically discussed with HES participants.

- **Measures recommended.** Vendor interviewees most often reported discussing rebates and financing for insulation (n=9) with HES participants; after insulation, they were most likely to say that the rebates and financing opportunities that they discussed were for "whatever [the participant] qualifies for" (n=7), in recognition of the various measure and customer eligibility requirements for the various loans (Table 39).
- **Financing recommended.** Turning to financing, "CHIF" led the list of financing options (n=13), with CHIF serving as the lender for the Energy Conservation Loans and the Residential Energy Efficiency Financing Program. Other common financing options included the Smart-E Loans, including the solar options covered by the Green Bank (n=9), and a generic reference to "on-bill" financing (n=6).[91]
- **Nomenclature used.** One small but critical element evident from Table 39 is that vendors generally refer to financing options by the organization that offers the financing rather than the name of the loan as it appears on the Energize Connecticut website. The one exception is Smart-E Loans, which vendors typically shortened to E-Loans. As shown in Table 25 above, end-users typically refer to either the selling feature of the loan (zero percent financing) or its name (Residential Energy Efficiency Financing, Energize Connecticut Heating Loan). Additionally, as part of the document review, the study notes that links from the Energize Connecticut website sometimes refer to the same loan with a different name. For example, the CHIF website includes a link[92] that still references the "HES Micro Loan" and the "HES Comprehensive Loan," even though most of the other links on the CHIF website and the Energize Connecticut website instead discuss the

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[90] One vendor did not have adequate time to answer these questions.
[91] Which could be either the Energize Connecticut Heating Loan or the Residential Energy Efficiency Financing Program
[92] http://www.chif.org/page/energy-efficiency-loans

Residential Energy Efficiency Financing Program.[93] The different nomenclature used by vendors, on websites, and in program documents may add to customer confusion over financing and the various options available mentioned by participants and vendors.

Table 39: HES Vendor Interviewees – Rebates and Financing Options Discussed with Participants[1]

(All 23 vendors responded)

Rebates	Number of Mentions	Financing	Number of Mentions
Insulation	9	CHIF[3]	13
Whatever they qualify for or is in the POD[2]	7	Smart-E Loans / Green Bank (solar)	9
All possible rebates	4	On-bill repayment[3]	6
Windows	3	In-house (offered by vendor)	3
HVAC Equipment	3	Small third-party financer	2
Appliances	1	AFC[4]	2
Solar	1		

[1] As a reminder, see http://www.energizect.com/your-home/solutions-list?ptype=1 for more detail on the rebate and financing options available to residential customers.
[2] "Print on Demand" booklet with recommendations and information on rebates and financing that gets left with the participant at the end of the assessment.
[3] Most likely refers to the Energize Connecticut Heating Loan program or the Residential Energy Efficiency Financing Program.
[4] Most likely refers to the Energize Connecticut Heating Loan program, financed by AFC First Financial Corporation.

[93] http://www.chif.org/page/borrower-information-and-application

- ***Vendors use the personalized assessment information packet as a tool for participants.***

When asked what information they leave with participants to help them make choices about measure upgrades, rebates, and financing, most vendors mentioned the POD booklet, including the list of recommendations, rebates, and financing options (Table 40). Note that the POD is another example of divergent nomenclature used by vendors and end-users, with the latter typically talking about an assessment report. This is likely a small point, as the vendors probably do not use the program acronym with customers, but it may ease conversations to use consistent terminology in program implementation manuals, between the Companies and vendors, and between vendors and participants.

Table 40: HES Vendor Interviewees – Material Left with Participant at End of Assessment

(All 23 vendors responded)

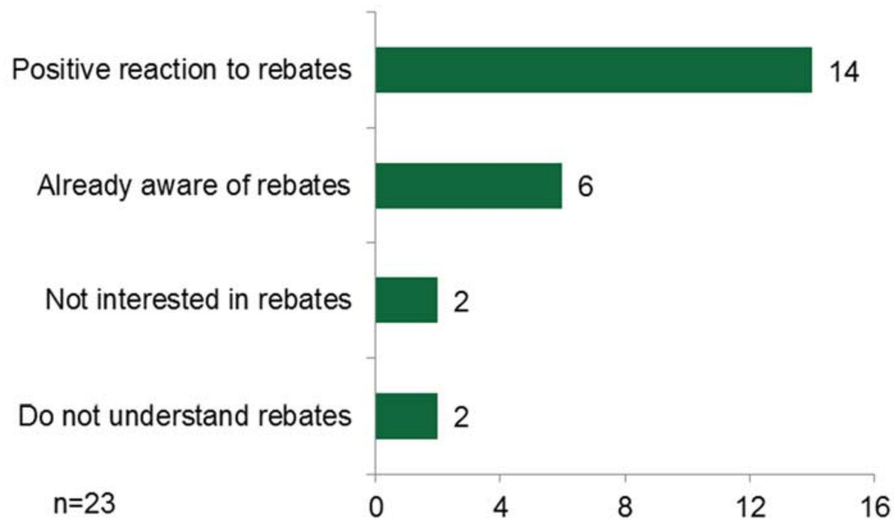
Materials Left	Number of Mentions
POD booklet	19
Utility Literature	4
Proposals and Cost estimates	4
Point to website	3
Rebate forms	3
Loan brochures	3
Marketing materials	2
Spreadsheets	1
Community literature	1

3.5.2 Participant Reactions to Rebates and Financing

- ***Vendors receive positive reactions to rebate opportunities and find that participants seek out the program with rebates in mind.***

As shown in Figure 41, vendors report that participants generally respond positively to rebate information (n=14). Some vendors highlighted that participants often know about rebates before the assessment and set up the visit specifically to find out if they were eligible for a desired measure (n=6).

Figure 41: HES Vendor Interviewees – Participant Reactions to Rebates
(Multiple responses, all 23 vendors responded; count of responses)



- ***Vendors find that customers are overwhelmingly enthusiastic about the amount of the insulation rebate.***

> "Insulation is very appealing because it's a big number—50%. That's huge!"
>
> *– HES vendor*

When asked which rebates customers like the most, the 23 vendors resoundingly named insulation (full list in Appendix A.3.3). Importantly, only three vendors cited the promised energy savings as being a driver for the insulation rebate; instead, the depth of the rebate—50% of cost—explained its appeal to participants.

While insulation is by far the most popular rebate, vendors did mention that participants are also drawn to the more tangible rebates, such as windows and heating equipment, as opposed to solar, where the installer receives the rebate.[94]

[94] Two also noted that participant reactions to rebates depends on their own situation—if they had electric baseboard heat and found out they were eligible for ductless heat pumps, then they may prefer that incentive over insulation. The smaller amount of the rebates relative to costs and to insulation and the fact that customers will "buy them anyway" served as explanations for why participants did not get terribly excited about appliance rebates.

> “[Participants] are ecstatic at having the financing rolled into their utility bill.”
>
> *– HES vendor*

- ***Vendors observe varied reactions to financing opportunities; zero percent financing and on-bill repayment opportunities are attractive to some, but others are simply averse to or disinterested in financing***

In contrast to rebates, vendors showed less agreement on participant reactions to financing options.

- **Positive reactions.** Eight vendors suggested that participants were interested in financing, while nine other respondents noted specific characteristics of the financing packages participants appreciated (Figure 42), specifically zero percent financing (n=4), instant approval for those with strong bill payment histories (n=3), and on-bill repayment (n=2). This signals their customers’ reported attraction to the Residential Energy Efficiency Financing Program administered by CHIF.[95] Vendors spoke of the enthusiasm that they observe among participants:

  [Participants] are excited when we tell them about the zero percent financing.

- **Negative reactions.** In contrast, five of the vendors said participants are not interested in financing, with reactions ranging from explicit lack of interest to passive lack of interest. For example, one vendor noted that many of the participants already had loans on homes, cars, or other items and “are not crazy about another financing option.” One vendor believed that the financing does not entice people who had no plans to do work to change their minds:

  I don’t know that financing . . . necessarily encourages people to do the work. I don’t think they [think], “Well, we weren’t thinking about doing the insulation, but this deal is so good we’re going to do it.”

- **Dependent reactions.** Finally, a vendor who serves both single-family and multifamily residences offered a unique perspective: While single-family homeowners rarely voiced interest in financing, “[The multifamily landlords] like hearing about financing if they don’t have that capital; the big seed-based options are attractive to them.”[96]

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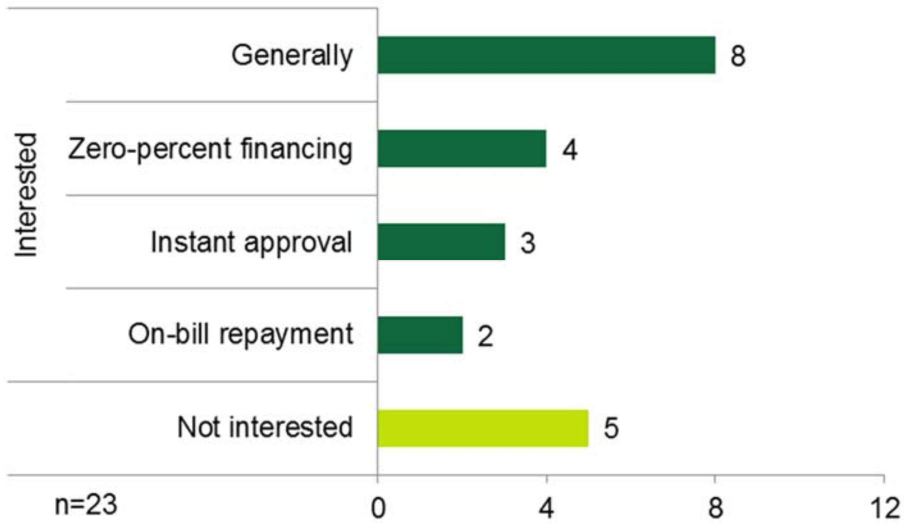
[95] The Residential Energy Efficiency Financing Program terms include these characteristics.
[96] “Big seed” refers to landlord eligibility for $3,500 per unit up to $100,000 available through Energy Conservation Loan Program and other loan programs.

Figure 42: HES Vendor Interviewees – Participant Interest in Financing
(Multiple responses, all 23 vendors responded; count of responses)



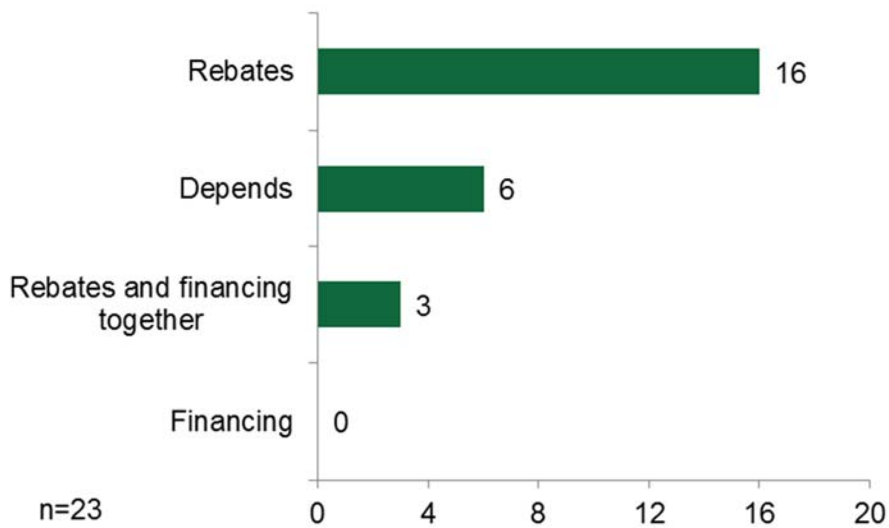
➢ ***Vendors emphasize zero percent financing and on-bill repayment opportunities, but try not to be invasive.***

Vendors were asked how they respond to customers who initially say they are not interested in financing. In general, vendors explained that they simply stressed the zero percent financing, on-bill repayment, and instant approval possibilities. One vendor attempted to lay out the costs for them—the price of the measure adjusted for rebates, the amount the borrower had to put down, the amount to be financed, and what that would mean to their monthly electric bill. A few left literature or followed up with phone calls, but most simply respected the participants' wishes not to discuss financing. "We don't want to be pushy" or "That is their personal financial situation" were common responses.

- ***Vendors generally find that participants prefer rebates over financing.***

The study also asked vendors to weigh in on whether participants preferred rebates, financing, or a combination of the two. Overwhelmingly, the vendors selected rebates (n=16; Figure 43). In fact, *not a single vendor said that participants prefer financing over rebates*, although some did note that the preference depended on the participant's personal situation (n=6). For example, if they needed a "big ticket item," the participant may prefer financing over rebates. Three vendors said that participants like rebates and financing in combination, which is actually the option end-users said they preferred (Table 29).

Figure 43: HES Vendor Interviewees – Participant Preferences for Rebates vs. Financing
(Multiple responses, all 23 vendors responded; count of responses)



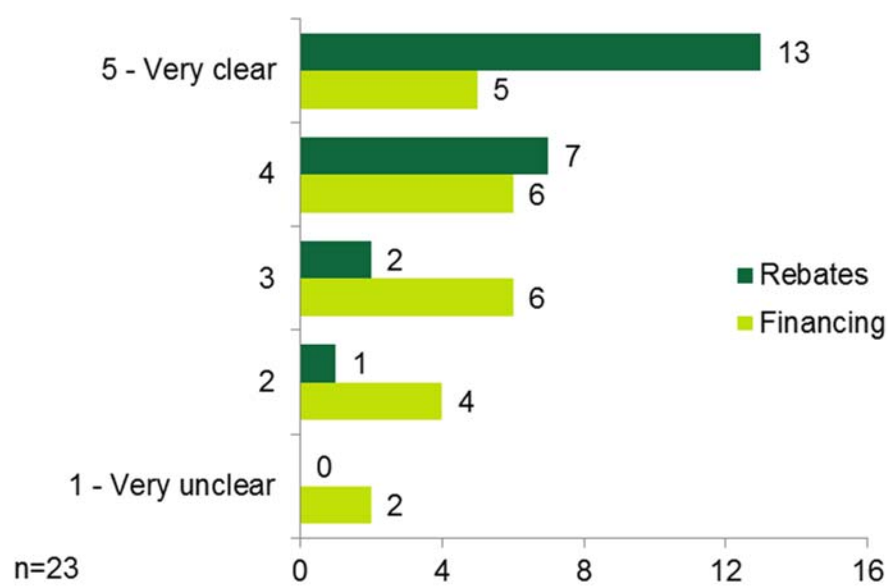
➢ ***Vendors understand and can explain program rebate structures and processes to customers, but some, along with their customers, struggle with the legalistic terminology and complexities involved in financing options***

As shown in Figure 44, vendors generally believed that the rebate information was clear, but they offered mixed opinions on the clarity of financing information.

- **Rebate clarity.** Regarding rebates, vendors explained that some customers—and even HES technicians—may find the rebate information confusing due to "small print," but most of the vendor staff understood the rebate structures and processes and could explain them to participants.
- **Financing clarity.** The same was not true of financing information. Vendors complained of "legalese" and "too many options" as well as confusion over which financing program covered which measures for which group of customers, especially given the amount of finance offerings available. Thus, the information was confusing both to the vendor staff and to the participants. Two vendors made a point of saying that they felt that, as far as legal documents go, the HES-related financing information and agreements were fairly clear, yet many of their customers still had too little experience with legal documents to be able to decipher the agreements.

Figure 44: HES Vendor Interviewees – Clarity of Rebate and Financing Information

(Multiple responses, all 23 vendors responded; count of responses)



➢ ***Vendors offered varied suggestions for program improvements, including altering the program structure or enhancing program rebate and financing processes.***

Finally, the vendors offered opinions on ways to improve rebates and financing. Some of their ideas are presented below. Please note that the study offers these as information only and not necessarily as specific recommendations.

- Extend the cutoff date for using rebates (up to a year)
- Reduce the “fine print” in the PODs
- Simplify financing options, applications, materials; use language that is easily accessible to the layperson
- Improve CHIF financing approval turnaround time
- Develop a way to run preliminary estimates accounting for rebates, financing, amount to put down, amount to be borrowed, and impact on energy bill; essentially, “what it would look like in payment terms or payments per month”
- Use a mid-stream model that issues rebates to vendors rather than to participants
- Rebate more measure types, increase rebate amounts, and begin offering rebates for hot water heater again[97]
- Smart-E Loan program should consider small credit unions as partners

3.6 Benchmarking – Decision Making and Financing

➢ ***Awareness levels of program financing, relative importance to encouraging add-on measures, and usage rates are comparable to neighboring states, but its application process appears to be more challenging.***

The study benchmarked four parameters within the decision making and financing findings:

- **Awareness.** Awareness among Connecticut HES participants of program financing (60%) is somewhat lower than that of their counterparts in Massachusetts, 69% of whom are aware of the Massachusetts HEAT Loan; however, awareness is considerably higher in comparison to Efficiency Maine participants and nearly the same as among New York HPwES participants. Comparing awareness of the various financing programs among nonparticipants, Connecticut HES nonparticipating customers (41%) are somewhat more aware than Massachusetts customers (32%).
- **Importance.** It appears that program financing is somewhat more important for encouraging Connecticut HES participants that used financing (86%) to move forward with making improvements than for their Massachusetts counterparts (81%) and notably more important than for New York HPwES participants (71%).[98]

[97] The Companies currently incent domestic hot water heaters upstream instead of downstream: incentives are given to retailers and distributors.
[98] Note that HPwES program structure is not perfectly comparable to HES program structures; however, they both involve home energy assessments that make recommendations for deeper measures.

- **Application.** Connecticut HES participants (43%) are less likely than their Massachusetts counterparts (97%) to find the program financing applications easy. This may reflect the fact that Massachusetts relies on a single loan for all eligible measures and households than having numerous loans that target different measures and households. A review of the Massachusetts application forms may offer some insights into ways to make them more accessible to Connecticut households.
- **Uptake.** The portion of HES participants in Connecticut that use program financing (10%) is comparable to that of HES participants in Massachusetts (9%).

Table 47 presents additional details.

Table 41: Decision-Making and Financing Results – Benchmarking

Benchmarking Parameter	Comparison Program		Connecticut HES Value	Notes / Considerations
	Program	Value		
Awareness				
% of HES participants aware of financing / loans	MA HES[1]	69%	60%	The MA, ME, and NY studies use binary awareness responses (yes/no), and this study uses a 4-point scale (ratings of 3 and 4 count as aware)
	Efficiency ME[2]	37%		
	GJGNY[3]	59%		
% of nonparticipants aware of financing / loans	GJGNY	32%	41%	
Importance				
% of financing-users reporting that financing was important in decision to move forward	GJGNY	71%	86%	Both the NY study and this study use a 5-point scale (counting ratings of 4 and 5 as important)
	MA HES	81%		The MA report asks if it enabled them to make improvements that they would not have (yes/no); this study uses a 5-point scale (counting ratings of 4 and 5 as important)
Experience				
Ease of filling out financing application	MA HES	97%	43%	The MA report uses a 4-point (counting ratings of 3 and 4) scale and this study uses a 5-point scale (counting ratings of 4 and 5)
Usage				
% of HES participants using program financing	MA HES	9%	10%	The MA report bases it on program tracking data and this study bases it on self-report

[1] Cadmus. *Massachusetts Home Energy Services Initiative and HEAT Loan Delivery Assessment*. July 31, 2015. http://ma-eeac.org/wordpress/wp-content/uploads/HES-and-HEAT-Loan-Program-Assessment-Final-Report.pdf.

[2] Opinion Dynamics and Dunsky Energy Consulting. *Evaluation of the Efficiency Maine Trust PACE, Power Saver, and RDI Programs. Final Evaluation Report. Volume II: Residential Direct Install Program.* October 23, 2013. http://www.efficiencymaine.com/docs/RDI-Final-Evaluation-Report-FINAL.pdf.

[3] NMR. *Process Evaluation and Market Characterization and Assessment: Green Jobs – Green New York Residential Program*. September 2012.

4 Section 4 Short-Term Persistence Findings

To estimate persistence, the study used on-site visits at HES-IE multifamily projects, CATI surveys with HES/HES-IE occupants, and in-depth interviews with HES-IE landlords and property managers. The evaluation results indicate that 1) persistence of measures verified as installed is high, 2) some inconsistencies with program tracking data result in an excess of installed measures, and 3) program light bulbs are removed because they burn out, and water-saving measures are removed because participants do not like them.

4.1 On-site Findings – Short-term Persistence

➢ ***On-site visits find an excess of measures compared to program tracking databases but limited measure removals—all persistence rates exceed 90%.***

The on-site visits resulted in three primary findings on short-term persistence:

- **Excess of measures.** CFLs and other measures showed *higher* observed counts than what has been recorded in the tracking database. Only LEDs diverged from this pattern.
- **Limited measure removal.** Field technicians did not find evidence that tenants had removed a large number of measures, based on verification rates and survey responses.
- **CFL burnout.** For those occupants citing removals, the primary reason was a result of burnt-out lamps; however, they reported removing only 18 out of 295 CFLs that they verified they had received.

An excess of program measures found on site creates a complication in determining which values should be used to estimate a verified installation rate relative to the tracking data. Table 42, which provides a summary of verification results by measures, includes all sites and units where a measure was recorded in the tracking database or where a measure was verified by tenants to have been installed through the program. When interpreting results, take note of the small sample sizes of units for LEDs and refrigerators.

Table 42: HES-IE Short-Term Persistence On-Site Visits – Summary of Results by Measure

Measure	Sites Visited[1]	Housing Units Visited[1]	Qty: Tracking Database	Qty: Verified Received	Qty: Verified Installed	Verified Installation Rate	Precision at 90% Confidence Level	Measure Persistence Rate[2]	Precision at 90% Confidence Level
CFLs	12	70	256	295	275	107%	41%	93%	4%
LEDs	3	17	88	41	41	47%	147%	100%	14%[3]
Faucet Aerators	12	83	58	111	107	184%	54%	96%	3%
Showerheads	12	83	27	56	53	196%	61%	95%	7%
Refrigerators	3	5	2	3	3	150%	446%	100%	35%[3]

[1] The counts of sites/housing units assessed where one or more units had the given measure installed according to tracking data, or tenant, or landlords or property managers. Take careful note of the small sample size of units for LEDs and refrigerators when interpreting the results.
[2] For a 100% measure persistence rate, there is no observed variability around which to estimate uncertainty; however, the Wilson binomial formula for estimating uncertainty associated with a sampled proportion provides an estimate even in such circumstances. That is the basis for the precision estimate.

- ***Data inconsistencies are not frequent enough to cause overwhelming concern, but the program may want to consider additional verification of measure quantities installed.***

As noted, the evaluation found some inconsistencies between measures recorded in the tracking data and those found on site, but these inconsistencies were not frequent enough to overwhelmingly point to any major program or measure-specific issues.

- **Excess of measures.** For all measures except LEDs, field technicians verified a few more measures on site than were reported in the tracking data. The evaluation found this to be the case for two sites with CFLs, four sites with hot water measures (faucet aerators and efficient-flow showerheads), and two sites with refrigerators. One speculation is that these measures may have been installed using a different pool of money (e.g., WAP) at the same time as the HES-IE measures. Tenants and landlords/property managers would be unable to distinguish between HES-IE and WAP lamps.
- **Zero or low installation rates.** Conversely, the visits found some sites where fewer measures were installed than were reported. Some examples are discussed below. The most severe of these discrepancies included one site where the tracking data showed seven CFL installations per unit for one site, but field technicians found only circline fluorescent fixtures installed through the program. The technicians' conversations with both tenants and landlords or property managers at this site indicated that they never received CFLs through the program.

4.1.1 CFLs

The evaluation identified approximately 7% more CFLs on site than were reported in the program data. In most cases, the tenants stated that they had purchased and installed the additional lamps either before or after participating in the program, and the analysis excludes such bulbs. Additionally, only six tenants across all the buildings visited reported that any of the program CFLs had failed since installation.

Table 43 shows the response dispositions and quantity verification that the analysis used in calculating the verification rate.

Table 43: HES-IE Short-Term Persistence On-Site Visits – CFL Verified Installation and Persistence Rates

CFL Disposition	Number of Lamps
A. Lamps in Tracking Database	***256***
B. Lamps Verified Received	***295***
Not received	-73
Received in excess of tracking database	112
C. Lamps Verified Installed	***275***
Broken/burn out	18
Missing other / reason not reported	2
Verified Installation Rate (C ÷ A)	***107%***
Persistence Rate (C ÷ B)	***93%***

4.1.2 LEDs

According to the tracking data, three of the sites assessed had LEDs installed. At two of those sites, the study was able to verify that all of the installed LEDs remained installed. However, at the third site, only 16 of 64 LEDs reported were installed—neither tenants nor landlords and property managers were able to confirm receiving more LEDs than what were currently installed, leaving most of the missing LEDs unaccounted for. The study provides little evidence that the *lower* observed counts of LEDs reflect removals by the landlord or tenants to resell the products, as the undercount was distributed across units, and tenants in units independently confirmed that they had not received those LEDs. In addition to the high persistence rate, it should be noted that tenants anecdotally expressed higher satisfaction with LEDs than with CFLs, in terms of both aesthetics and performance.

Table 44 shows the response dispositions and quantity verification that the analysis used in calculating the verification rate.

Table 44: HES-IE Short-Term Persistence On-Site Visits – LED Verification and Persistence Rates

LED Disposition	Lamps
A. Lamps in Tracking Database	***88***
B. Lamps Verified Received	***41***
Not received	-47
Received in excess of tracking database	0
C. Lamps Verified Installed	*41*
Broken/burn out	***0***
Missing other / reason not reported	***0***
Verified Installation Rate (C ÷ A)	***47%***
Persistence Rate (C ÷ B)	***100%***

4.1.3 Faucet Aerators

The evaluation found that 97% of the faucet aerators installed through the program were still installed. Only four of 111 aerators verified as received had been removed.

Table 45: HES-IE Short-Term Persistence On-Site Visits – Faucet Aerator Verification and Persistence Rates

Aerator Disposition	Aerators
A. Aerators in Tracking Database	***58***
B. Aerators Verified Received	***111***
Not received	-3
Received in excess of tracking database	56
C. Aerators Verified Installed	***107***
Broken	4
Missing other / reason not reported	*0*
Verified Installation Rate (C ÷ A)	***184%***
Persistence Rate (C ÷ B)	***96%***

4.1.4 Efficient-flow Showerheads

The evaluation found that all but three of the low-flow showerheads installed through the program were still installed. The tenants who removed two of the showerheads did so because they needed physical disability-accessible units.

Table 46: HES-IE Short-Term Persistence On-Site Visits – Showerhead Verification and Persistence Rates

Showerhead Disposition	Showerheads
Showerheads in Tracking Database	***27***
Showerheads Verified Received	***56***
Not received	-3
Received in excess of tracking database	32
Showerheads Verified Installed	***53***
Broken	1
Missing other / reason not reported	2
Verified Installation Rate (C ÷ A)	***196%***
Persistence Rate (C ÷ B)	***95%***

4.1.5 Refrigerators

Field technicians were not able to verify the two refrigerator units that were listed in the program tracking data associated with the sites. Both the tenants and the program vendor confirmed that they never intended to install refrigerators at those two locations. Technicians did, however, find six refrigerators ostensibly installed through the program at two other sites.

Table 47: HES-IE Short-Term Persistence On-Site Visits – Refrigerator Verification and Persistence Rates

Refrigerator Disposition	Refrigerators
Refrigerators in Tracking Database	***2***
Refrigerators Verified Received	***3***
Not received	-2
Received in excess of tracking database	3
Refrigerators Verified Installed	***3***
Missing other / reason not reported	0
Verified Installation Rate (C ÷ A)	***150%***
Persistence Rate (C ÷ B)	***100%***

4.2 End-User Participant Surveys – Short-Term Persistence

➢ ***End-users remove light bulbs and water-saving measures because they do not like them, they break, or they do not work properly.***

Light bulbs and water-saving measures had the highest reported removal rates among HES and HES-IE survey respondents (Table 48). On average, HES respondents removed those measures about three and a half months after participating, and HES-IE participants removed them roughly five months after participating. Note that the percentages of self-reported removals among these occupants exceed the on-site verified removal rate in HES-IE multifamily units discussed above. Most often, respondents removed CFLs, along with other core service measures, because they simply did not like them, they broke, or they did not work properly (Table 92 in Appendix A.4). HES participants most often reported that they removed measures because they did not like them (compared to other reasons for removal), while HES-IE respondents most often reported that they removed measures because the products broke (compared to other reasons for removal).

Table 48: End-user Participant Survey Respondents – Verified Measures, Removal Rate, and Timing of Removal

Measure	HES			HES-IE		
	N	% Removed	Average Time Removed[1]	N	% Removed	Average Time Removed[1]
Light bulbs	481	14%	3.4	431	11%	5.2
Water saving measures	247	7%	3.5	330	7%	4.9
Air Sealing	292	2%	3.8	281	1%	1.3
Water pipe wrap	225	<1%	4.0	107	2%	4.0
Duct sealing	81	2%	4.0	27	4%	12.0

Note: Responses are unweighted.
[1] Indicates average number of months from installation to removal.

4.3 HES-IE Landlord and Property Manager Interviews – Short-Term Persistence

➢ ***Landlords and property managers report limited measure removal.***

Only two landlords and property managers indicated that measures installed through the program had been removed, both saying that very few items were removed (Table 118 in Appendix B.2.3 includes more details). Water-saving measures were removed because tenants did not like them, and CFLs were removed because they had burnt out.

4.4 Benchmarking – Short-term Persistence

➢ ***Connecticut CFL verification rates are somewhat high compared to other programs***

Given the unique participant segment targeted for visual inspection in this research effort (i.e., low-income, multifamily occupants) and specific research objective (i.e., short-term measure persistence) of this study, it is somewhat challenging to identify directly comparable studies for benchmarking purposes. Two CFL studies appeared to be comparable to this one; as reported above, the Connecticut HES-IE on-site visits revealed a CFL verification rate of 107% and a CFL persistence rate of 93%:

- A Northeast Energy Efficiency Partnerships (NEEP) commercial and industrial study that included *some* multifamily units in its commercial-based sample found that the 10-year persistence rate for compact fluorescent lamps (CFLs) was 33% and the two-year persistence rate was 73%.[99] Both rates are notably lower than that of this R4 study.[100]
- In Michigan, a recent evaluation of Consumers Energy's Income Qualified Program conducted a combination of phone and on-site verification, finding a CFL verification rate of approximately 89%—somewhat lower than this R4 study.[101]
- More in line with the R4 study, in Ohio, evaluations of Dayton Power and Light's Low-Income Weatherization Program have used phone surveys to identify a CFL in-service rate of 97%.[102]

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[99] KEMA. *C&I Lighting Measure Life and Persistence Project: Final Report*. Prepared for NEEP 2010. Available online: http://issuu.com/neepenergy/docs/neep_ci_persistence_report-final/1?e=12509042/8424638
[100] Given that this Connecticut study took place in 2015 and the NEEP report was published five years before that, it is possible that the quality and lifetime expectations of CFLs were not as advanced which may impact results.
[101] Using a nested sampling approach, the evaluation found a 98% verification rate for installed CFLs through a phone survey, then found through on-site assessments that verified 91% of the phone survey responses. Cadmus, 2015. Income Qualified Program Evaluation Report – 2014 Program Year. Consumers Energy. Jackson, MI.
[102] Cadmus, 2015. 2014 Evaluation, Measurement, and Verification Report. For Dayton Power and Light. Dayton, OH.

5 Section 5 Net-to-Gross Findings

The study relied on industry best practices to estimate net-to-gross (NTG) ratios for HES, HES-IE, and rebate-only programs using findings from CATI surveys with end-user participants and in-depth interviews with HES-IE landlord and property manager participants. Within energy efficiency program evaluation, exact calculations of NTG vary by program administrator, program and measure type, and data availability. Yet most definitions—including those used in Connecticut—include the following:[103]

- **Free Ridership**: The proportion of participants who would have implemented the program measure a) within a specified time period, b) at the same efficiency level, and c) in the absence of the program (see Table 50 below for more discussion on these components).
- **Spillover**: Reductions in energy consumption and/or demand caused by the presence of an energy efficiency program, beyond the program-related gross savings of the participants and without financial or technical assistance from the program. Spillover can manifest in participants (who take actions beyond the program) and nonparticipants who adopt energy-efficient measures or behavior due to program influence (e.g., after being exposed to program marketing or acting on the recommendation of a participant).

The NTG ratios are estimated using free ridership and spillover rates that are weighted and then input into this formula:

$$(1 - Free\ ridership) + Spillover = \ Net\ to\ gross\ ratio$$

In Connecticut, NTG serves as a component of the net realization rate using the following equation:[104]

$$(Gross\ realization\ \%)\ x\ (Installation\ rate\ \%)\ x\ (100\%\ -\ Free\ ridership\%\ +\ Spillover\%)$$

The evaluation measured free ridership for HES, HES-IE, and rebate-only participant end-users and landlords as well as spillover for HES and HES-IE participant end-users and landlords. Estimates are provided for the program overall and for individual measures. Note that Connecticut only tracks NTG for individual measures at this time.

The study estimated weighted NTG ratios of 0.80 for HES, 0.95 for HES-IE, and 0.93 for rebate-only programs. The evaluation suggests not using the HES-IE and rebate-only NTG ratios formally because low-income programs generally assume a NTG ratio of 1.0, and sample sizes are small among rebate-only respondents. The

[103] Definitions and discussion are modified from NMR Group and Research Into Action. 2010. *Net Savings Scoping Paper*. Final delivered the Northeast Energy Efficiency Partnership's Evaluation, Measurement, and Verification Forum November 13, 2010. Available at: http://www.neep.org/net-savings-scoping-paper-1.
[104] Note that the last set of parentheses in the equation are the same as the NTG ratio equation, but converted to a percentage. For more information, see Appendix 3 in United Illuminating Company and Connecticut Light and Power. 2014. *Connecticut Program Savings Document: 10th Edition for 2015 Program Year.* Document dated November 5, 2014.

following section describes in more detail the free ridership and spillover rate algorithms and findings presented in Table 49.

When compared to similar programs in the Northeast, the HES NTG ratio is somewhat lower, with other programs having ratios greater than 1.0.

Table 49: HES, HES-IE, and Rebate-only Program Net-to-Gross Ratios

Rates and Ratio	HES	HES-IE[1]	Rebate-only[1]
Weighted free ridership rate	0.22	0.08	0.07
Weighted spillover rate	0.02	0.03	Not asked
Net-to-gross ratio	**0.80**	**0.95**	**0.93**

[1] The study recommends not using the HES-IE and rebate-only values as formal NTG ratios.

5.1 Free Ridership

As shown above, the study found weighted free ridership rates of 0.22 for HES, 0.08 for HES-IE, and 0.07 for rebate-only programs. The HES and rebate-only free ridership rates come from the results of the end-user participant surveys, and the HES-IE free ridership rate comes from the landlord and property manager interviews.

5.1.1 End-User Participant Surveys – Free Ridership

CATI survey questions asked 369 HES end-users free ridership questions about 601 randomly selected measures—representing 4,213.2 MMBtu/year in gross savings—that they had installed through the program.[105]

To estimate the HES free ridership rate, the analysis used the product of two scores:

- **Initial score.** Survey questions asked HES end-users if they had specific plans to install the measure in question prior to participating in the program. If they had no specific plans to install the *same* measure, the question series asked them if they would have installed that *kind* of measure at all, and if so what they would have installed or performed in terms of efficiency level and when they would have done it. If they had specific plans to install the same measure, then they received an initial free ridership score of 1.0 (full free rider). If they would not have installed that kind of measure in the absence of the program, then they received an initial free ridership score of 0.0 (non-free rider). For all other measures, when the end-user would have installed that kind of measure, the algorithm assigned initial free ridership scores ranging from 0.0 to 1.0, depending on their responses about efficiency level and timing. Appendix A.5.1 includes a flow chart illustrating this logic sequence.
- **Influence-rating score.** Using a scale of 1 to 5, where 1 means "no influence" and 5 means "a great influence," survey questions asked respondents to rate the level of influence of three program elements on their decision to install the measure. The analysis assigned scores ranging from 0.0 to 1.0 based on the maximum rating they gave to the influence of the incentive or rebate, the installation contractor, and program information. For example, a maximum rating of 1 received an influence rating score of 1.0 and a maximum rating of 5 received 0.0.

[105] The sampling defaulted to asking respondents about add-on measures wherever possible, and it assigned one to two measures about which to ask depending on what respondents installed and verified installing. The savings come from the program database; electric, gas, oil, and propane savings have been converted into MMBtu/year.

Table 50 outlines survey questions, response options, and the range of resulting initial and influence-rating free ridership rates associated with specific responses.[106]

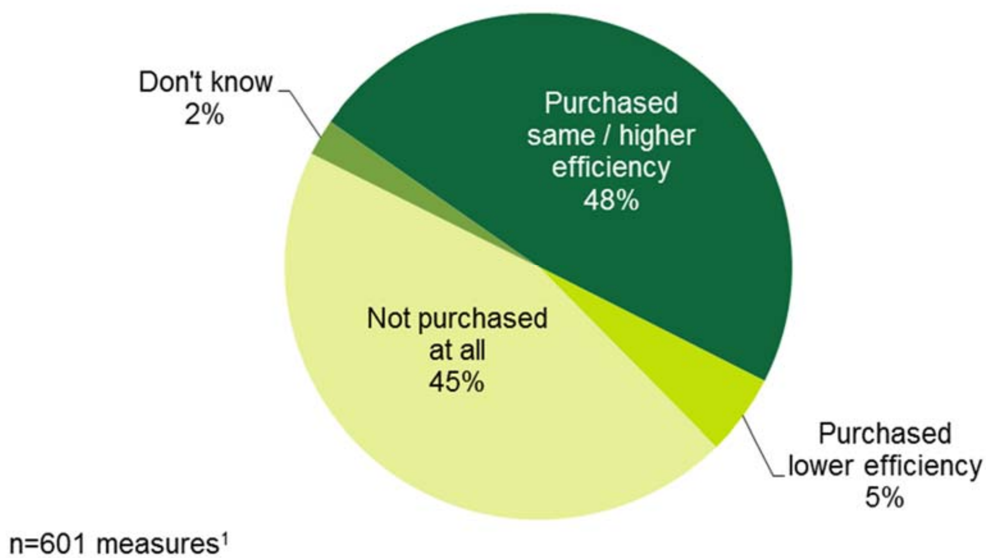
Table 50: End-user Participant Survey Respondents – Free Ridership Scoring Methods

Question wording	Response	Initial Free Ridership Score
Before learning about the program, did you have any **specific plans** to purchase and install the [MEASURE] that you installed through the program?	Yes	Automatic free rider (1.0)
	No / Don't know	Possible free rider (0.0 to 1.0)
Inter-related Considerations in Determining Initial Free Ridership Score[1]		
If you had not participated in the program, would you have purchased one that was a **more / same / less efficient**?	More / Same	Possible free rider (0.0 to 1.0)
	Less	Possible free rider (0.0 to 0.75)
	Not at all	Automatic non-free rider (0.0)
If you had not participated in the program, **when** would you have purchased/installed the measure?	Sooner / Same time / Within three months	Possible free rider (0.75 to 1.0)
	Within six months	Possible free rider (0.50 to 0.75)
	Within one year	Possible free rider (0.25 to 0.50)
	More than one year	Possible free rider (0.0 to 0.25)
Question Wording	**Maximum Rating**	**Influence Rating Free Ridership Score**
Please consider **how influential** the following elements were on your decision to install the measure. Please base your answer on a scale of 1 to 5, with 1 indicating "No influence on your decision to install it" and 5 indicating "had a great influence on your decision to install it." a. The utility company's incentive or rebate b. Installation contractor, if used c. Information from the utility company	1	Free rider (1.0)
	2	Partial free rider (0.75)
	3	Partial free rider (0.50)
	4	Partial free rider (0.25)
	5	Non-free rider (0.0)

[1] Any measures for which the interviewee expressed they did not have specific plans to install the measure in the absence of the program were asked about these remaining three inputs.

While end-users would have installed nearly one-half of the measures asked about (48%) at either the same or higher efficiency levels in absence of the program (Figure 45), the free ridership scores for those individual measures were diminished because of end-users' estimates of when they would have been installed or because of high influence ratings that end-users reported—indicating that the program still had an influence on their decision making even though they said that they would have purchased a high efficiency unit.

Figure 45: HES End-user Participant Survey Respondents – Action in Absence of Program Participation

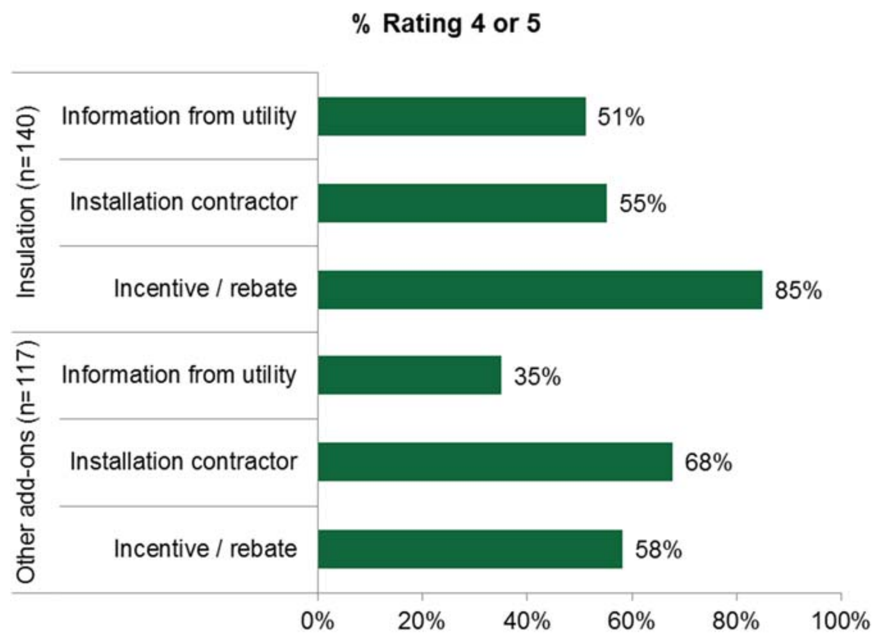


[1] The sampling chose the 601 measures by defaulting to asking end-users about program add-on measures (with greater preference on insulation), wherever possible, and it assigned one to two measures about which to ask depending on what they installed and verified installing.

[106] This approach was based on the methodology of an Energy Trust of Oregon evaluation: Research into Action. Production Efficiency Program: Process and Impact Evaluation. Appendix A. 2006.

Respondents gave high influence ratings to program incentives and rebates, particularly for insulation: nearly three-fifths (58%) of respondents gave add-on measures ratings of 4 or 5, and 85% gave rebates and incentives for insulation installations ratings of 4 or 5. Installation contractors (68%) had the highest influence on non-insulation add-on measures compared to the other two elements—information from the utility (35%) and incentives/rebates (58%; Figure 46).

Figure 46: HES End-user Participant Survey Respondents – Influence of Program Elements on Decision to Install



Note: The free ridership question series only asked the three influence questions about add-on measures (not core services). Responses are based on a five-point scale, with 1 indicating "no influence" and 5 indicating "a great influence."

After weighting the average free ridership scores for each measure by the number of measures (as compared to the population) and then by the sum of those measures' gross savings (including electric, gas, oil, and propane) recorded in the program tracking database (associated with the respondents), the analysis resulted in an HES free ridership score of 0.22 at the 90% confidence level with precision of +/- 3% (Table 51).

Free ridership for insulation, for which the study intentionally oversampled, was notably low when compared to the other frequently asked-about measures.[107] The most dramatic difference was between insulation and light bulbs; the free ridership rate for insulation was 0.06 (n=140), whereas for light bulbs (n=158) it was 0.55. As a "sensitivity analysis," the study calculated the free ridership rate in absence of insulation measures[108] and arrived at a somewhat higher overall free ridership rate of 0.26 versus a rate of 0.22 with insulation included. This difference demonstrates the high level of influence that the program has on the installation of insulation and the value of continuing to include insulation as a program measure.

Table 51: HES End-user Participant Survey Respondents – Free Ridership Rates

Measures (n=369 respondents)	n	Average Free Ridership Rate	Sum of Gross Savings (MMBtu/yr)[1]	Confidence Interval[2]	
				Maximum	Minimum
Air sealing	80	0.25	784.9	0.33	0.17
Duct sealing	27	0.18	271.4	0.30	0.06
Light bulbs	158	0.55	469.0	0.62	0.49
Water pipe wrap	66	0.28	51.9	0.37	0.19
Water saving	76	0.20	97.2	0.28	0.13
AC equipment	7	0.17	9.3	0.40	0.00
Clothes washer	1	0.00	1.2	0.00	0.00
Ductless HP	18	0.25	74.3	0.42	0.08
Geothermal HP	2	0.00	9.3	0.00	0.00
Heating equipment	10	0.14	133.6	0.33	0.00
Water heater	6	0.23	65.0	0.51	0.00
Windows	10	0.05	152.5	0.16	0.00
Insulation	140	0.06	2,093.6	0.09	0.03
Total	**601**		**4,213.2**		
Weighted Average Free Ridership Rates[3]					
With insulation		**0.22**		**0.25**	**0.19**
Without insulation		**0.26**		**0.30**	**0.23**

[107] The window free ridership rate was even lower than that of insulation, but the sample size for windows was quite small (n=10).
[108] The non-insulation measures included in the 0.26 estimate are both core services (air sealing, duct sealing, light bulbs, water pipe wrap, and water-saving measures) and other add-on measures besides insulation (AC equipment, clothes washers, heat pumps, hot water heaters, and windows).

[1] Savings in the program database are associated with the respective measure and respective interviewees. Electric, gas, oil, and propane savings have been converted into MMBtu/year.
[2] Figures are at a 90% confidence level.
[3] The free ridership rate is weighted by number of measures (as compared to the population) and by gross annual savings.

Short-term survey questions also asked 58 non-HES rebate-only participants free ridership questions about 63 measures representing 721.6 MMBtu/year in gross savings. The study estimated a free ridership rate of 0.07 for these measures. This ratio is not factored into the HES net-to-gross ratio and the study does not suggest adopting it as a formal free ridership rate because of small sample sizes and because the intent of the R4 study was not to establish a free ridership rate for non-HES/HES-IE participants, but rather to lay the ground work for an ongoing real-time data collection effort in the future. Comparing the average measure-specific free ridership rates between HES and rebate-only respondents indicates some differences between those that participated in the program and those that only received rebates. For example, the free ridership rate for HES participants' ductless heat pumps was 0.25, while among rebate-only respondents it was 0.15. However, sample sizes are too small to draw definitive conclusions about the measures. Appendix A.5.1 presents the rates by measure and confidence intervals.

Table 52: HES and Rebate-only End-user Participant Survey Respondents – Free Ridership Rates

	HES (n=369 respondents)[1]		Rebate-only (n=58 respondents)	
Measures	**N**	**Average Free Ridership Rate**	**n**	**Average Free Ridership Rate**
AC equipment	7	0.17	14	0.18
Air source HP	0	N/A	5	0.10
Ductless HP	18	0.25	34	0.15
Geothermal HP	2	0.00	2	0.12
Heating equipment	10	0.14	8	0.00
Total[2]	**601**	**0.22**	**63**	**0.07**

[1] The HES rows do not show the measures that were inapplicable to rebate-only respondents (i.e., measures only eligible through HES/HES-IE or measures not randomly selected for this module). The total number of measures (601) and weighted average free ridership rate (0.22) shown include those measures. Excluding the inapplicable measures, the weighted average free ridership rate among HES respondents would be 0.17 (n=37 measures).
[2] The overall free ridership rates are weighted by number of measures (as compared to the population) and by gross annual savings.

Table 53 lists the HES free ridership rates for individual measures as estimated from this study together with current assumed gross realization, installation, free ridership, spillover, and net realization rates as listed in the 2015 PSD. It also updates the net realization rate based on the NTG ratios for each measure. The table does not consider the estimated spillover rates for this study (discussed below) because the analysis only yields an overall spillover rate, not a measure-specific one. The study **does not recommend** updating every PSD free ridership or realization rate based on these revised estimates due to small sample sizes and wide confident intervals for some measures. Based on sample sizes and confidence intervals, the study suggests in Recommendation 17 updating the PSD for the following measures: insulation (0.06), water saving measures (0.20), and water pipe wrap (0.28). While the lighting measure has adequate sample sizes and confidence intervals, the fact that many light bulbs purchased in retail stores may have been supported through the upstream programs suggests the use of the upstream NTG of ratios of 51% for CFLs and 82% for LEDs (as reported in the R86 Lighting NTG and LED Market Assessment study).[109]

[109] NMR Group, Cadmus Group, and DNV GL. 2015. R86: Connecticut Residential LED Market Assessment and Lighting Net-to-Gross Overall Report. Delivered to the Energy Efficiency Board, May 2015. http://www.energizect.com/your-town/ct-residential-led-lighting-market-assessment-and-lighting-ntg-r86final

Table 53: Net-to-Gross – Implications for the 2015 Program Savings Document

Measures	Estimated HES Free Ridership Rate	2015 PSD Assumptions					Revised Net Realization Rate
		Gross Realization Rate	Installation Rate	Free Ridership Rate	Spillover Rate	Net Realization Rate	
Air sealing: Prescriptive	25%	7%	100%	0%	0%	7%	5%
Air sealing: Blower door	25%	90%	100%	0%	0%	90%	68%
Duct sealing	18%	90%	100%	0%	0%	90%	74%
Insulation	6%	70%	100%	0%	0%	70%	66%
Light bulbs	55%	100%	100%	0%	0%	100%	45%
Water pipe wrap[1]	28%	100%	100%	0%	0%	100%	72%
Water saving[1]	20%	100%	100%	0%	0%	100%	80%
Central AC equipment[2]	17%	100%	100%	42% Ev. 26% UI	0%	58% Ev. 74% UI	83%
Clothes washer[3]	0%	94%	100%	0%	0%	93%	94%
Ductless HP (single family)	25%	63%	100%	0%	0%	63%	47%
Heating equipment	14%	64%	100%	0%	0%	64%	55%
Water heater	23%	100%	100%	0%	0%	100%	77%
Windows	5%	100%	100%	0%	0%	100%	95%

[1] Not listed so assumed 100% values for PSD.
[2] The PSD presents separate estimates of free ridership for UI and Eversource (Ev.). We have listed both Companies' assumptions but the revised value is based on a single free ridership estimate from this study.
[3] Based on the appliances assumptions in the PSD.

When assessing the HES free ridership results by survey timing, the analysis shows a notable difference, with the short-term respondents' free ridership rates being significantly lower than that of other respondents (0.22 versus 0.15). This difference could reflect short-term respondents' better recalling their decision processes since the survey was soon after the measure was installed. Note that the short-term survey sample sizes are too small to draw any inferences about individual measures.

Table 54: HES End-user Participant Survey Respondents – Free Ridership Rates by Survey Timing

Measure	Long-term (n=317)			Short-term (n=52)		
	n	Average Free Ridership Rate	Sum of Gross Savings (MMBtu/yr)[1]	n	Average Free Ridership Rate	Sum of Gross Savings (MMBtu/yr)[1]
Air sealing	74	0.26	742.7	6	0.13	42.1
Duct sealing	23	0.20	234.5	4	-	36.9
Light bulbs	145	0.56	439.5	13	0.53	29.5
Water pipe wrap	57	0.29	44.0	9	0.25	7.8
Water saving	67	0.18	84.2	9	0.32	13.1
AC equipment	6	0.20	7.9	1	-	1.4
Clothes washer	1	-	1.2	-		-
Ductless HP	11	0.31	58.6	7	0.03	15.7
Geothermal HP	1	-	2.5	1	-	6.8
Heating equipment	5	0.21	89.7	5	0.02	43.9
Water heater	4	0.07	47.9	2	0.67	17.15
Windows	6	0.03	92.9	4	0.08	59.6
Insulation	115	0.04	1,645.9	25	0.11	447.9
Total	**515**		**3,491.6**	**86**		**721.6**
Weighted Average Free Ridership Rates[2]						
With insulation		**0.22***			**0.15**	
Without insulation		**0.27***			**0.16**	

* Indicates statistically significant difference across time periods at the 90% confidence level.
[1] Savings values in the program database are associated with the respective measure and respective interviewees. Electric, gas, oil, and propane savings have been converted into MMBtu/year.
[2] The free ridership rate is weighted by gross annual savings in addition to number of measures in the population.

5.1.2 HES-IE Landlord and Property Manager Interviews – Free Ridership

Interview questions asked 29 landlords and property managers questions related to free ridership for 55 randomly selected measures they had installed through the program.[110]

[110] The sampling defaulted to asking them about add-on measures wherever possible and asked them about one to three measures, depending on what they installed and the time available to complete the interview.

To estimate the HES-IE landlord and property manager free ridership rate, the interviews asked a similar series of questions as used in the CATI surveys of the end-users, but took a somewhat different approach: if they indicated that they had specific plans to install the measure in question prior to participating in the program, interviewers asked them about what they would have installed or performed in terms of quantity, efficiency level, and timing. If they had not had specific plans or would not have installed the measure in the absence of the program, then the algorithm automatically assigned the measure a free ridership rate of 0.0. The rates for all other responses ranged from 0.0 (non-free rider) to 1.0 (full free rider) depending on the combination of responses that are shown in Table 55. Appendix A.5.1 includes examples of combinations of responses and the resulting scores that the study assigned.

Table 55: HES-IE Landlord and Property Manager Interviewees – Free Ridership Scoring Methods

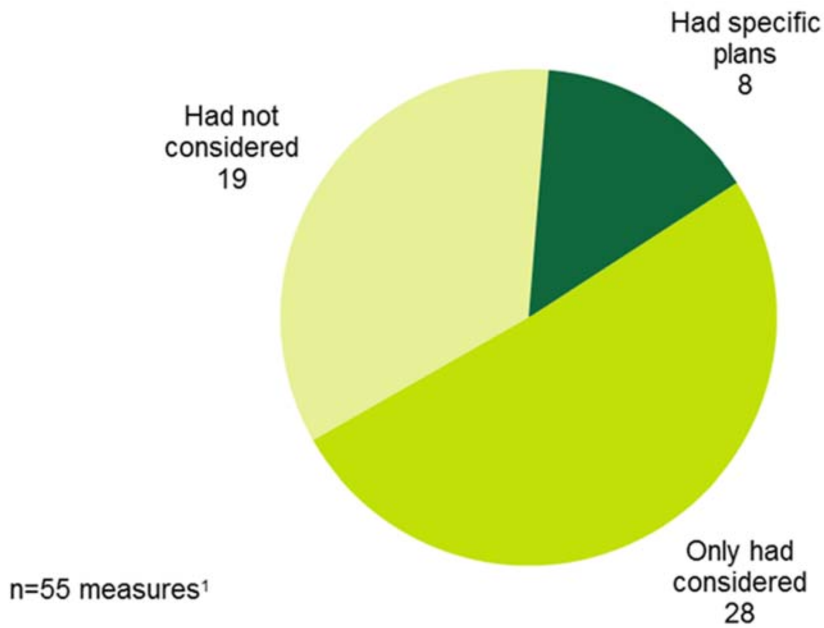
Question wording	Response	Result
Prior to taking part in the program, had you **considered** installing this measure in any of your units in this building?	Yes	Possible free rider (0.0 to 1.0)
	No / Don't know	Automatic non-free rider (0.0)
Did you have **specific plans** to install this measure prior to taking part in the program?	Yes	Possible free rider (0.0 to 1.0)
	No / Don't know	Automatic non-free rider (0.0)
Inter-related Considerations in Determining Free Ridership[1]		
If you had not participated in the program, please think about how your decisions might have changed regarding installation of the **amount / number of units of the measure / number of housing units**?	Fewer / Same / More	Possible free rider (0.25 to 1.0)
	None	Automatic non-free rider (0.0)
If you had not participated in the program, please think about how your decisions might have changed regarding **level of efficiency installed**?	Lower / Same / Higher	Possible free rider (0.25 to 1.0)
	None	Automatic non-free rider (0.0)
If you had not participated in the program, please think about how your decisions might have changed regarding **timeline of installation**?	Sooner / Same time / Within three months	Possible free rider (0.75 to 1.0)
	Within six months	Possible free rider (0.50 to 0.75)
	Within one year	Possible free rider (0.25 to 0.50)
	More than one year	Possible free rider (0.0 to 0.25)

[1] For any measures for which the interviewee expressed specific plans to install the measure in the absence of the program, the interviewee was asked about these remaining three inputs. If they would have installed the measure, the study then considered the combination of these elements to estimate a free ridership score between 0.25 and 1.0.

Landlords and property managers reported having specific plans to install eight of the 55 measures before participating in the program (Figure 47).

Figure 47: HES-IE Landlord and Property Manager Interviewees – Plans for Measure Installation before Program Participation

(Count of measures)



[1] The participants verified that they had installed these 55 measures either as HES-IE free core service or as incented add-on measures.

For most (five) of the eight measures that they had specific plans to install, the interviewed landlords planned to install the same efficiency level as those that they eventually had installed through the program. Generally, they would have installed the measures at later dates than they did (five) and would have installed the same quantities (four).

Table 56 shows the average free ridership rates by measure. After being weighted by the number of interviewees asked about that measure type, the study found an overall weighted free ridership rate of 0.08 for HES-IE.

Table 56: HES-IE Landlord and Property Manager Interviewees – Free Ridership Rates

Measure	Count of interviewees	Average free ridership rate
Water saving	15	0.10
Light bulbs	12	0.16
Air sealing	4	0.00
Pipe wrap	1	0.00
Lighting equipment	9	0.00
Insulation	8	0.00
Refrigerators	3	0.60
HVAC equipment	1	0.00
Hot water heater	1	0.00
Windows	1	0.92
Weighted free ridership rate[1]		**0.08**

[1] Free ridership rates are weighted by the number of interviewees responding about the specific measure types.

5.2 Spillover

As described earlier, the second input into the net-to-gross ratio is the spillover rate.

- **Non-rebated measures.** To estimate the spillover rate, interviews began by asking participating end-users and landlords/property managers if they had made any energy efficiency upgrades that had not received rebates or incentives since participating in the program.
- **Program influence level.** If they had done so, respondents rated the program's level of influence on their decision. If they considered the program as having had influence on their decision to make the upgrade, the study considered them to be spillover-eligible measures.
- **Weighting by savings.** For end-users, the analysis weighted the percentage of respondents installing a spillover-eligible measure by the average savings in the program database (or other sources where possible and necessary) associated with that measure type. The weighted average proportion of respondents installing particular measures represented an initial spillover value.
- **Adjusting for additional factors.** The estimate integrated the possibility that light bulbs were already incented through upstream program efforts and, therefore, halved the average savings as a proxy for its value in the weighting process. Additionally, the surveys and interviews did not collect two measure characteristics that are integral to estimating associated savings: 1) the quantities/number of units or 2) the efficiency levels of the spillover-eligible measures. To take this parameter into account, the algorithm counted one-third of the initial weighted spillover value. A percentage of 33% seemed to be a conservative estimate for awarding the program

some spillover credit where it was due but also making an educated assumption that participants are likely installing fewer quantities or lower efficiency levels of program-incented measures than what are performed through the program. Regardless, given the small percentages of respondents installing the particular spillover-eligible measures, the study observed that using a proportion of 33% (as compared to 10% or 90%, for example) did not present a major difference. For example, the HES weighted spillover value was 0.06, resulting in an adjusted spillover value of 0.02 [*0.06 * (1/3)*].

The study arrived at a spillover rate of 0.02 for HES based on end-user survey responses and 0.03 for HES-IE, which is the weighted average of the results from HES-IE end-user survey responses (0.03) and HES-IE landlord and property manager interviews (0.03).[111] The study did not ask short-term (R31) study respondents about spillover given the relatively short time span between participation and survey completion.[112]

Critically, the approach likely underestimates spillover because it does not factor in nonparticipant spillover, which, due to program marketing, increased availability of products, and word-of-mouth from participants, can be substantial. Future study designs that focus more exclusively on NTG estimation should consider using alternative survey questions or even a completely different approach that would allow for the more precise estimation of overall and measure-specific spillover for both participant and non-participant end-users.

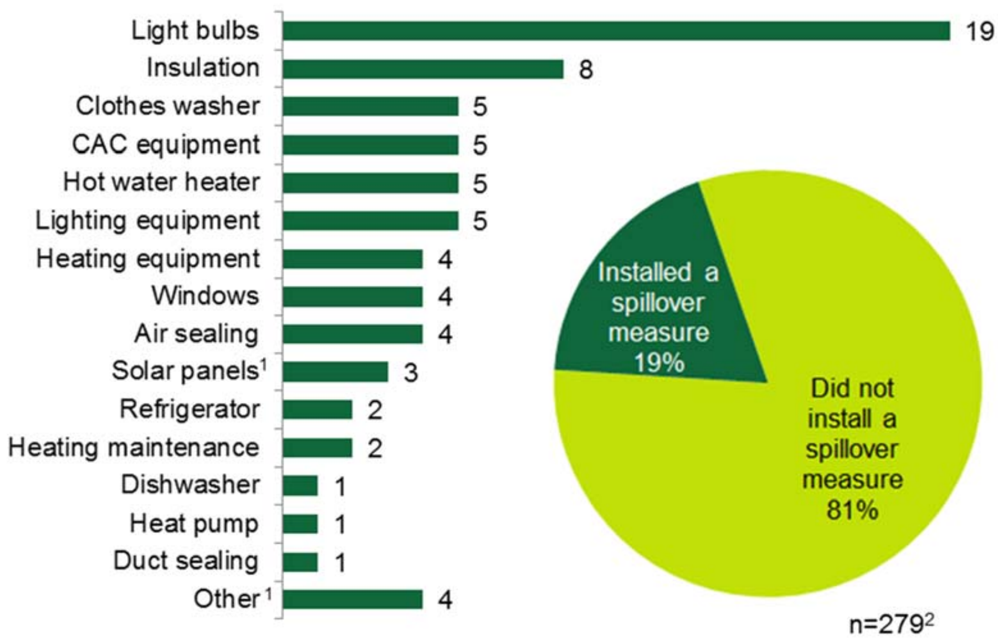
5.2.1 HES – Spillover

As illustrated in Figure 48, nearly one-fifth of the HES respondents who were asked about spillover (19%) had installed or performed an energy-saving measure that did not receive an incentive following their participation in the program *and* indicated that their decision to move forward was influenced by the program—meaning that they rated the program's level of influence on their decision to install or perform the measure a 3 or higher on a scale of 1 to 5, where 1 means "no influence" and 5 means "a great influence." In total, they listed 73 measures that were influenced by the program, making those measures eligible for spillover; most often they mentioned light bulbs (26% of measures) and insulation (11% of measures).

[111] This ratio is weighted by number of program contacts present in the end-user population and landlord and property manager population. Because both spillover rates are the same, the weighted value appears the same.
[112] Spillover among this population can be assessed in future evaluation efforts.

Figure 48: HES End-user Participant Survey Respondents – Spillover Measures

(Multiple responses, count of measures)



Note: Percentages are weighted and counts are unweighted.
[1] These measures are not in the HES program savings database.
[2] Represents the number of respondents asked about spillover. Fifty-four respondents installed one or more spillover-eligible measures.

After weighting the percentage of respondents reporting each spillover measure by the average savings values present in the program database associated with the respective measure type (where possible), the analysis resulted in an average spillover value of 0.06 for the HES program; the adjusted spillover value for the HES program is one-third of that initial value, or 0.02.

Table 57: HES End-user Participant Survey Respondents – Spillover Rate

Program-Influenced Measure Installed Outside of Program	% of Respondents (n=279)[1]	Average Gross Savings (MMBtu/yr)[1]
Light bulbs	40%	1.6
Insulation	13%	12.3
Lighting equipment	11%	1.6
Hot water heater	10%	11.2
CAC equipment	10%	1.1
Clothes washer	8%	0.7
Refrigerator	7%	0.9
Air sealing	6%	4.8
Heating equipment	4%	6.4
Windows	4%	11.3
Duct sealing	3%	3.8
Solar panels[2]	3%	11.2
Heating maintenance[2]	2%	13.6
Heat pump	1%	1.0
Dishwasher	1%	0.8
Initial weighted spillover	**0.06**	
Adjusted spillover	**0.02**	

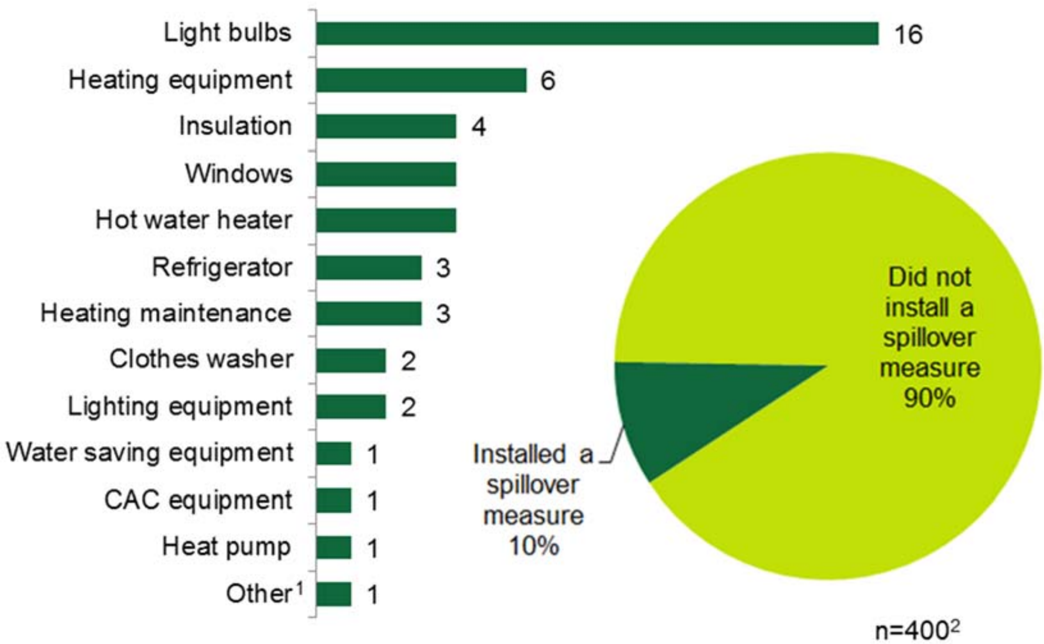
Note: Percentages are weighted.
[1] Average savings in the program database associated with each measure. Electric, gas, oil, and propane savings have been converted into MMBtu/year. The initial spillover rate is the average of the proportions of respondents naming the spillover measure weighted by the average gross annual savings. The adjusted spillover is one-third of that value.
[2] Solar rebate program data were not readily available; therefore, solar panel estimates come from calculations using PV Watts' online calculator tool, which can be found here: http://pvwatts.nrel.gov/pvwatts.php. The estimate does not include the *Other* category because of lack of savings data.

5.2.2 HES-IE – Spillover

As illustrated in Figure 49, 10% of HES-IE end-users each installed one or more spillover-eligible measures. Like HES end-users, HES-IE end-users most frequently reported light bulbs as their spillover measures (19%).

Figure 49: HES-IE End-user Participant Survey Respondents – Spillover measures

(Multiple responses, count of measures)



Note: Percentages are weighted and counts are unweighted.
[1] These measures are not in the HES program savings database.
[2] Represents the number of respondents asked about spillover. Thirty-eight respondents installed one or more spillover-eligible measures.

These responses, once weighted by the average program savings by measure, result in a spillover rate of 0.08 among HES-IE end-users; the adjusted spillover value is one-third of that, or 0.03.

Table 58: HES-IE End-user Participant Survey Respondents – Spillover Rate

Program-Influenced Measure Installed Outside of Program	% of Respondents (n=400)	Average Gross Savings (MMBtu/yr)[1]
Light bulbs	42%	1.6
Insulation	11%	12.3
Lighting equipment	6%	1.6
Hot water heater	11%	11.2
CAC equipment	2%	1.1
Clothes washer	5%	0.7
Refrigerator	7%	0.9
Air sealing	-	4.8
Heating equipment	16%	6.4
Windows	11%	11.3
Water-saving equipment	2%	0.8
Heating maintenance	8%	13.6
Heat pump	3%	1.0
Initial weighted spillover	**0.08**	
Adjusted spillover	**0.03**	

Note: Percentages are weighted.
[1] Average savings in the program database associated with the respective measure. Electric, gas, oil, and propane savings have been converted into MMBtu/year. The initial spillover rate is the average of the proportions of respondents naming the spillover measure weighted by the average gross annual savings. The adjusted spillover is one-third of that value.

Three HES-IE landlords and property managers reported making three energy efficiency upgrades following participation in the program that did not receive rebates or incentives but were influenced by the program (Appendix A.5.2); the study considers these three measures to be spillover measures. Because all three interviewees named different measures, and each represented 3% of the sample, there is no need to weight the measures by savings. Their responses result in a spillover rate of 0.03 among HES-IE landlords and property managers. Averaging this rate with end-user participants' spillover rate—which also was 0.03—the resulting spillover value was 0.03.

5.3 Benchmarking – Net-to-Gross

Table 59 compares this study's estimates of Connecticut HES free ridership, spillover, and overall net-to-gross values with other recent estimates from the Northeast:

- **Free ridership.** The HES program-wide free ridership rate of 0.22 is slightly higher than the free ridership values estimated for Efficiency Maine and NYSERDA, which vary from 0.14 to 0.20. The HES free ridership values for insulation, air sealing, and CFL measures differ somewhat from those found in Massachusetts, with

Connecticut insulation free ridership (0.06) being much lower than that of Massachusetts (0.25), and Connecticut CFL and air-sealing free ridership rates (0.25 and 0.55)[113] being higher than those in Massachusetts (0.08 and 0.29, excluding non-participant spillover).[114]

- **Spillover.** Connecticut HES spillover is lower than that of nearby programs, except in the case of light bulbs where the Massachusetts participant spillover rate is 0.03 and that of Connecticut (even when adjusted for upstream incentives) is seven times higher (0.20). Additionally, unlike the Massachusetts study, the Connecticut study estimate includes other light bulbs, not just CFLs (e.g., LEDs), which might even point to a greater value.
- **Net-to-gross.** The Connecticut HES overall NTG ratio is 0.80, while neighboring programs have values greater than 1.0. However, the insulation NTG ratio for Connecticut (1.07) is higher than that of Massachusetts (0.95, excluding non-participant spillover).

Table 59: Net-to-Gross Results – Benchmarking

Net-to-Gross Element	Measurement Level	Comparison Program		Connecticut HES Ratio / Value
		Program	Ratio / Value	
Free Ridership Rate	Program-wide	Maine RDI[115]	0.18	0.22
		Maine HESP[116]	0.14	
		NYSERDA HPES[117]	0.20	
	Insulation	Massachusetts HES[118]	0.25	0.06
	Air Sealing		0.08	0.25
	CFLs / light bulbs		0.29	0.55
Participant Spillover	% participants installing	Maine RDI	28%	19%
	Program-wide		0.77	0.02
	Program-wide	NYSERDA HPwES[119]	0.14	
	Insulation	Massachusetts HES	0.20	0.13
	Air Sealing		0.08	0.06
	CFLs / light bulbs		0.03	0.20
Net-to-Gross	Program-wide	Maine RDI	1.59	0.80

113 It should be noted that most air sealing that participants may have done on their own would likely not have been blower-door guided.
114 The Massachusetts report includes nonparticipant spillover in the overall NTG calculations; however, we have included only free ridership and participant spillover here in order to facilitate direct comparisons with the Connecticut results.
115 Evaluation of the Efficiency Maine Trust PACE, Power Saver, and RDI Programs. Final Evaluation Report. Volume II: Residential Direct Install Program. Opinion Dynamics and Dunsky Energy Consulting. October 23, 2013.
116 Efficiency Maine Trust Home Energy Savings Program Final Evaluation Report. Cadmus Group. November 30, 2011.
117 NYSERDA 2007-2008 Home Performance with ENERGY STAR Program Impact Evaluation Report. Megdal & Associates. September 2012.
118 Home Energy Services Net-to-Gross Evaluation - Part of the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group and Navigant. June 2012.
119 The NYSERDA HPES and Massachusetts HES reports both include nonparticipant spillover in the overall NTG calculations; however, we have included only free ridership and participant spillover here in order to facilitate direct comparisons with the Connecticut results.

		NYSERDA HPwES	1.08	
		Massachusetts HES	1.13	
	Insulation		0.95	1.07
	Air Sealing		1.00	0.81
	CFLs / light bulbs		0.73	0.65

6 Section 6 Non-Energy Impacts Findings

Non-energy impacts, or NEIs, refer to benefits or drawbacks that participants, utility companies, and society can experience as a result of program efforts that do not tie directly to energy use or savings. This study assessed NEIs from the participant perspective only.[120] They can considerably affect a participants' decision to adopt a measure and their experience with the measure post installation.

To develop non-energy impact (NEI) rates, in-depth interviews and CATI surveys asked end-user HES and HES-IE CATI survey respondents and HES-IE landlords and property manager interviewees if the program had a positive, negative, or no effect on various non-energy-related elements in their households or properties. Additionally, using similar questions, CATI surveys asked nonparticipant end-users to speculate on the types of non-energy impacts that they could imagine might happen; the analysis used their responses to contextualize end-user participants' responses to NEI questions. Interviews with HES vendors also involved discussion of NEIs, but the analysis does not use those findings to estimate any NEI values.

For any elements where participants observed positive or negative impacts as a result of the program, questions asked them to compare the value of that NEI to the impact of the program on energy savings. After asking about individual NEIs, the questions asked them to consider the net impacts of NEIs combined—qualitatively and quantitatively. From these inputs, the study estimated NEI values.

The analysis resulted in NEI values of **0.87** for HES end-users, **0.90** for HES-IE end-users, and **0.73** for HES-IE landlords and property manager participants.[121] Meaning that, on average, for every $100 worth of savings that they/their tenants experience on their energy bills, HES-IE landlords and property managers consider that non-energy impacts add an additional $73 of value, for example. In other words, the NEI values can be considered as multipliers that are applied to energy savings (e.g., 73% * expected energy savings). For further explanation behind the methodology for calculating these values, see Appendix A.6.1. Adding them to the programs' total resource BCR could mean increases over the 2016 to 2018 program period in total resource benefits of **$155.6 million** for HES (45% increase) and **$95.6 million** for HES-IE (64% increase) and utility benefits of **$76.6 million** for HES (45% increase) and **$70.9 million** for HES-IE (86% increase).

[120] Societal impacts might include improvements in public health or economic improvements. An impact on utilities might include improvements customers' ability to pay their energy bills, resulting in financial benefits to the utility company.
[121] Rebate-only respondents received an NEI value of 1.24; however, the sample size was small with only 54 respondents being factored into the estimate while both HES and HES-IE estimates came from sample sizes greater than 350 (Figure 51).

6.1 Adding Non-Energy Impacts Values to Program Benefits

The study estimated, in terms of dollars, the potential impact of adding the NEI values to the programs' total resource and utility BCRs. The process for doing this involved four primary steps:

- First, identifying the total resource costs and benefits and utility resource costs and benefits for each utility and for each fuel type reported in the 2016-2018 plan[122]
- Second, removing the plan's NEBs from the total resource benefits which were present for Eversource Electric and Yankee gas and then estimated proportionally for UI, SCG, and CNG[123]
- Next, adding the R4 end-user NEI values (0.87 for HES and 0.90 for HES-IE) to the total resource and utility cost BCRs (revised to exclude the plan's NEBs in the case of total resource BCRs)
- Last, multiplying the revised BCRs by the plan's costs to estimate revised benefit increases

For example, the HES total resource BCR would increase from 1.92 to 2.79 and the HES-IE total resource BCR would increase from 1.40 to 2.30; this could mean increases in total resource program benefits of **$155.6 million** for HES (45% increase) and **$95.6 million** for HES-IE (64% increase). The addition of the NEI values could increase the utility resource benefits by **$76.6 million** for HES (45% increase) and **$70.9 million** for HES-IE (86% increase). Table 60 and Table 61 present the inputs into the estimates and also show the impact of distributing the NEIs proportionally by the program costs allocated to each fuel type.[124]

[122] Connecticut General Statutes-Section 16-245m(d), 2016-2018 Electric and Natural Gas Conservation & Load Management Plan, October 1, 2015.
[123] Itemized NEBs were equal to roughly 1% of total resource benefits for Eversource Electric and 0% for Yankee Gas.
[124] Note that the sum of the revised benefits associated with each fuel type do not equal the total revised benefits because the sum of the original BCRs for each fuel type are greater than the overall original BCR.

Table 60: Non-Energy Impacts – Addition to Total Resource Program Benefits

(Dollars in millions)

Row	Input/Result	Explanation	HES[1]			HES-IE		
			Electric	Gas	Total	Electric	Gas	Total
A	Total Resource Costs[2]	Sum of all electric and gas utilities	$104.6	$74.3	$178.9	$66.8	$39.5	$106.3
B	% of Costs	Portion allocated to fuel type	58%	42%		63%	37%	
C	Total Resource Benefits[2,3]	Sum of all electric and gas utilities	$270.5	$72.7	$343.2	$97.6	$51.4	$149.0
D	Total Resource Benefit Cost Ratio	Row C / Row A (including for total)	2.59	0.98	1.92	1.46	1.30	1.40
E	Estimated NEI by Program and Fuel	Row B x Estimated NEI by program[4]	0.51	0.36	0.87	0.57	0.33	0.90
F	Revised Total Resource Benefit Cost Ratio	Row D + Row E (including for total)	3.10	1.34	2.79	2.03	1.64	2.30
G	Revised Total Resource Benefits	Row A x Row F	$323.7	$99.5	$498.8	$135.4	$64.6	$244.6
H	**Increase in Benefits**	**Row G - Row C**	**$53.2**	**$26.9**	**$155.6**	**$37.9**	**$13.2**	**$95.6**
I	**% Change in Benefits**	**Row H / Row C**	***20%***	***37%***	***45%***	***39%***	***26%***	***64%***

[1] Includes HVAC/Water heaters
[2] Source: Connecticut General Statutes-Section 16-245m(d), 2016-2018 Electric and Natural Gas Conservation & Load Management Plan, October 1, 2015; individual tables for each utility
[3] Total Resource Benefits exclude non-energy benefits (NEBs) as listed in the plan. Because the plan does not specify NEBs for UI, CNG, and SCG, the calculations shown here have applied ratios derived from Eversource Electric and Yankee Gas.
[4] Distributed overall NEI values (HES = 0.87 and HES-IE = 0.90) proportionately between the two fuel types by the amount of costs allocated to the respective fuel type (row B)

Table 61: Non-Energy Impacts – Addition to Utility Program Benefits

(Dollars in millions)

Row	Input/Result	Explanation	HES[1]			HES-IE		
			Electric	Gas	Total	Electric	Gas	Total
A	Utility Costs[2]	Sum of all electric and gas utilities	$44.6	$43.4	$88.1	$39.3	$39.5	$78.7
B	% of Costs	Portion allocated to fuel type	51%	49%		50%	50%	
C	Utility Benefits[2]	Sum of all electric and gas utilities	$100.5	$69.0	$169.5	$36.9	$45.2	$82.1
D	Utility Benefit Cost Ratio	Row C / Row A (including for total)	2.25	1.59	1.92	0.94	1.15	1.04
E	Estimated NEI by Program and Fuel	Row B x Estimated NEI by program[3]	0.44	0.43	**0.87**	0.45	0.45	**0.90**
F	Revised Utility Benefit Cost Ratio	Row D + Row E (including for total)	2.69	2.02	2.79	1.39	1.60	1.94
G	Revised Total Utility Benefits	Row A x Row F	$120.1	$87.7	$246.1	$54.5	$63.0	$152.9
H	**Increase in Benefits**	**Row G - Row C**	**$19.6**	**$18.7**	**$76.6**	**$17.7**	**$17.8**	**$70.9**
I	**% Change in Benefits**	**Row H / Row C**	***20%***	***27%***	***45%***	***48%***	***39%***	***86%***

[1] Includes HVAC/Water heaters
[2] Source: Connecticut General Statutes-Section 16-245m(d), 2016-2018 Electric and Natural Gas Conservation & Load Management Plan, October 1, 2015; individual tables for each utility
[3] Distributed overall NEI values (HES = 0.87 and HES-IE = 0.90) proportionately between the two fuel types by the amount of costs allocated to the respective fuel type (row B)

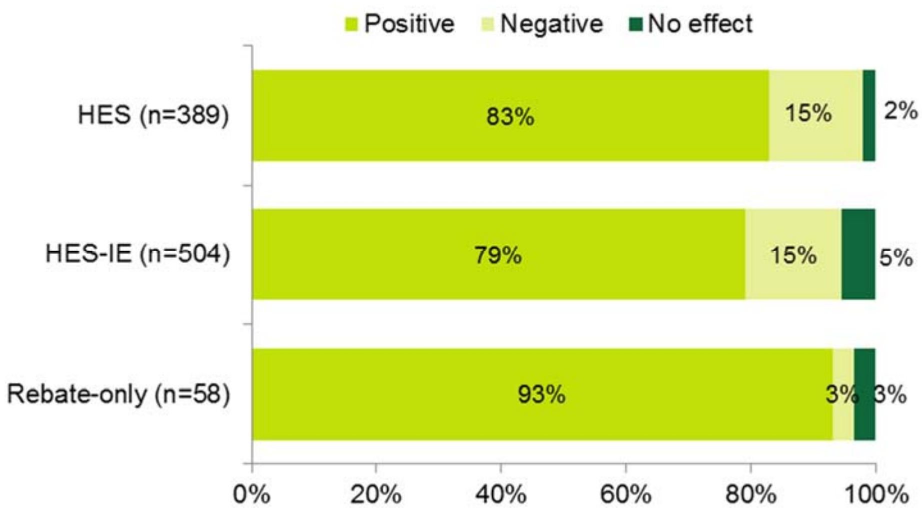
6.2 End-user Participant Surveys – Non-Energy Impacts

➢ ***End-user participants experience high levels of positive net non-energy impacts.***

The vast majorities of HES (83%), HES-IE (79%), and rebate-only (93%) end-user participants observed positive net impacts from NEIs (Figure 50). In general, end-user participants said they experienced NEIs that aligned with their expected NEIs, although this did vary to some extent.

Figure 50: End-user Participant Survey Respondents – Net Non-Energy Impacts

(Percentage of respondents)



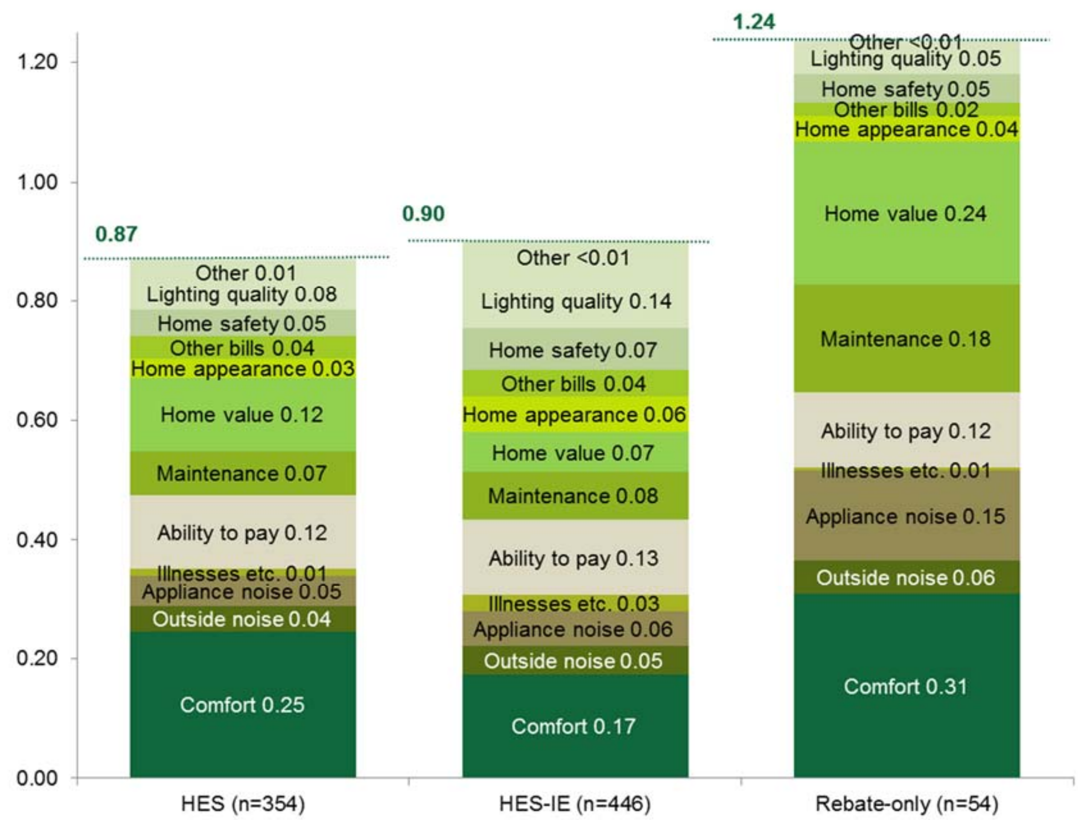
Note: Responses are weighted.

Surveys asked end-user participants if the program had a positive, negative, or no effect on each of the following elements: the comfort of the home, outside noise, appliance or equipment noise, illnesses and missed days from work or school, equipment maintenance and durability, ability to pay energy bills or other bills (e.g., water bills), lighting quality, safety from other improvements or new equipment, home appearance and value or the ability to sell it, or any other NEIs they may have noticed. Responses to these questions indicated the following:

- As proportions of the overall NEI values among HES (0.87) and HES-IE (0.90) participants, comfort carried the greatest importance for both (0.25 and 0.17), accounting for 28% (HES) and 19% (HES-IE) of the NEI values.
- Positive impacts on improved lighting quality for HES-IE participants 0.14), ability to pay energy bills for both HES and HES-IE participants (0.12 and 0.13) and increased home value or ability to sell for HES participants (0.12) contributed relatively large portions to overall NEI values.

- Rebate-only end-users placed the greatest importance on the positive impacts on their comfort (0.31), composing nearly one-third of their overall NEI value of 1.24; they also placed a great deal of importance on the positive impacts on their homes' value/ability to sell their homes (0.24) and equipment maintenance (0.18).
- While few reported negative impacts, those who did most often reported that the quality of their lighting had been negatively impacted.

Figure 51: End-user Participant Survey Respondents – Distribution of Non-Energy Impact Values



Note: Sample sizes do not include all respondents that were asked the NEI module. Some respondents gave responses that resulted in outlier values; other respondents did not know the magnitude of effects despite identifying them as positive or negative. The analysis excluded them from the NEI values. Appendix A.6.1 provides greater explanation.

6.3 End-user Nonparticipant Surveys – Non-Energy Impacts

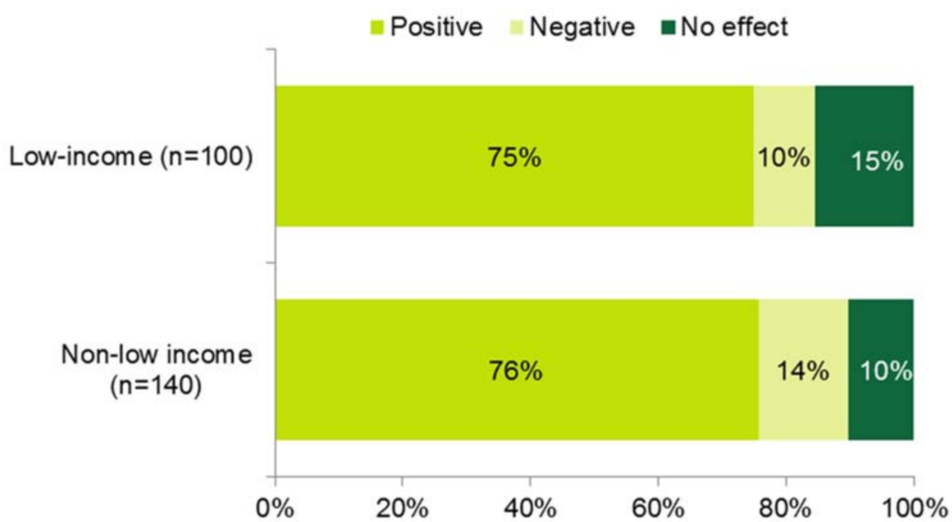
➢ ***Nonparticipants project net-positive NEIs.***

When not prompted with specific examples, most nonparticipant end-user survey respondents could not name any NEIs that might result from a program like HES/HES-IE. Low-income respondents speculated that there would be non-energy impacts more frequently than NLI respondents. Of those who did offer some possible NEIs, most nonparticipant respondents speculated that their ability to pay energy bills, comfort, and appliance or HVAC system noises would be positively impacted. (Appendix A.6.3 illustrates these results in greater detail.)

Once the survey asked about specific impacts, nonparticipant respondents voiced higher levels of expected NEIs: the majorities of NLI (76%) and low-income (75%) nonparticipants hypothesized that they would experience net-positive impacts from NEIs (Figure 52). When compared with their HES and HES-IE participant counterparts' actual experiences, nonparticipants were more likely to estimate that there would be no effect and less likely to estimate that there would be a positive effect.

Figure 52: Nonparticipant Survey Respondents – Net Non-Energy Impacts

(Percentage of respondents)



Note: Responses are weighted

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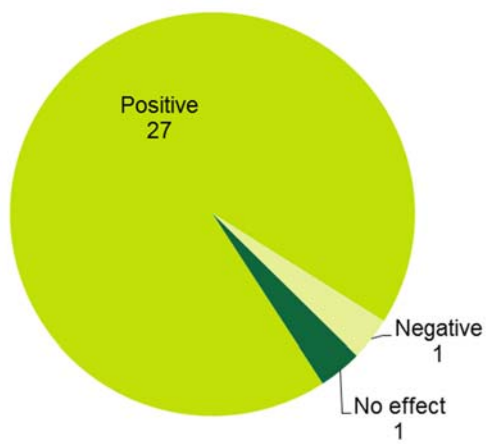
6.4 HES-IE Landlord and Property Manager Interviews – Non-Energy Impacts

➢ ***Interviews indicate high NEI values among landlords and property managers***

As reported, the NEI value among HES-IE landlords and property managers was 0.73. Nearly all interviewees (93%) reported positive net impacts resulting from NEIs (Figure 53).

Figure 53: HES-IE Landlord and Property Manager Interviewees – Net Non-Energy Impacts

(Count of interviewees)



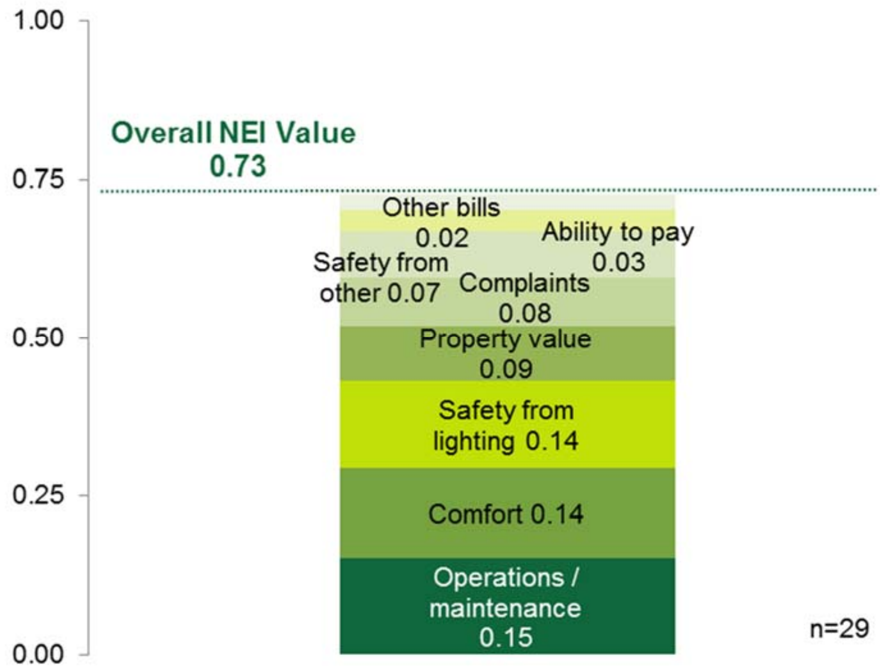
➢ ***Landlords and property managers observe positive impacts on operations and maintenance, tenant comfort, and safety.***

In-depth interviews asked landlords and property managers if the program had a positive, a negative, or no effect on each of the following elements: the comfort of the residents, operations and maintenance, tenant complaints, tenant ability to pay rent, the amount of other bills (e.g., water bills), safety from improved lighting, safety from other improvements or new equipment, property value or the ability to sell, or any other NEIs they may have noticed. As proportions of the overall NEI value of 0.73, operations and maintenance (0.15), tenant comfort (0.14), and safety from improved lighting (0.14) carried the greatest importance. One property manager interviewee reflected on the positive value of improving tenant comfort and operations and maintenance for their company:

> *[The first priority] is the comfort of our residents. [It matters] to us in the office because when we have happier residents, we have fewer things to work on. We spend less time going up to people's apartment to fix maybe a window draft or things like that. And plus we want our residents to be comfortable.*

Figure 54 illustrates how the individual NEIs sum to 0.73.

Figure 54: HES-IE Landlord and Property Manager Interviewees – Non-Energy Impacts Values



- ***Landlords and property managers report very few negative NEIs, but note some negative impacts on tenant complaints and safety.***

Landlords and property managers were very unlikely to report any negative NEIs—the only elements for which they reported negative NEIs were tenant complaints (10%) and safety (7%). For example, two interviewees received complaints about the dimness of the new lighting installed by the program,[125] both recounting how tenants have removed the lighting covers to remedy the issue:

> *There have been a ton of complaints about the energy-efficient [bulbs] installed in the apartments. The residents can't stand them, because they are not as bright as the previous [bulbs]. In fact, I have a ton of fixtures that our residents have asked us to remove the covers off the light fixtures because the lights are so dim. They don't help at all. But with the covers off they give a little more light.*

Two interviewees identified safety concerns from the air-sealing measures that needed to be remedied; the air sealing made it difficult to open windows or latch exterior doors closed. While one thought the problem outweighed the energy savings, the other thought it had much less negative value than the possible energy savings value:

> *It saves the energy, so it is worth doing it. It was worth it because they were doing a good job tightening things up [to stop air] leaks. Some of them were too tight for tenants, but it is still worth it.*

- ***NEIs are somewhat important drivers***

> "When we have happier residents we have fewer things to work on."
>
> *– HES-IE property manager*

NEIs were somewhat important in HES-IE landlords and property managers' decisions to participate in the program. Rating the importance of expected NEIs on their decision to participate in the program by using a scale of 1 to 5 where 1 equals "not at all important" and 5 equals "very important," on average, they rated the importance a 3.72 for themselves (n=27) and a 3.80 for their tenants (n=28). Before participating, the majority had some particular NEIs in mind that they thought would result from program participation (Figure 37 in Appendix A.6.4)—specifically, improving operations and maintenance, reducing tenants' complaints, and increasing tenants' level of comfort. In the words of one property manager,

> *We knew from experience that anything new would help improve [the property]. Most of the tenants are low-income and disabled. Anything they can get to improve their [lifestyle] makes it easier for them and for us.*

---

125 Despite this problem, one of these two interviewees thought that the program had a net positive impact on tenant complaints.

6.5 HES Vendor Interviews – Non-Energy Impacts

While end-users, landlords, and property managers may experience NEIs after installing measures, vendors have the opportunity of informing HES and HES-IE participants about the impacts they may experience as a result of installing both core measures and deeper measures. Vendors answered a series of questions about their discussions and promotions of NEIs to HES and HES-IE participants. A total of 16 vendors answered these questions, although not all of them responded to each question.

➢ ***Nearly all vendors discuss comfort and health and safety as positive non-energy impacts with program participants—and actually think participants will experience them.***

Of the 16 vendors asked about NEIs, 13 mentioned comfort and 11 mentioned health and safety (Table 62). Importantly, while vendors explained that participants may experience these impacts from core services, they stressed that installing deeper measures such as insulation or early replacement of heating systems will only increase the comfort and health and safety of the household. It is not surprising that vendors focus on these two measures, as most also believed that participants would actually see improvements to their comfort and health and safety, and, according to the vendors, participants seemed to care about these benefits more than others; the participant surveys discussed above support this belief. Some other NEIs mentioned by a few vendors included home value; outside noise; equipment maintenance, durability, and ease of operation; and ability to pay other bills.

Vendors also displayed an in-depth and nuanced understanding of what constitutes “comfort” and “health and safety.” For the latter, they included not only issues such as mold or asbestos insulation but also reduced fire hazards, indoor air quality, or the sealing of gaps and holes that let rodents and insects in. On comfort, one vendor explained that it was not just physical comfort but also the psychological comfort associated with equipment maintenance and reliability:

> *If [the measure is] heating or cooling they are [considering], they’ll save energy but [they are] also thinking, “Oh great! I can get rid of that system that doesn’t work, and it will be a more comfortable winter.” So it’s comfort in terms of peace of mind and then comfort physically.*

A few additional noteworthy observations from vendors on NEIs include the following:

- Vendors did not consider “ability to pay energy bills” to be a non-energy benefit. They believed participants would see lower energy bills, but vendors categorized this as an energy-related benefit—and the reason the programs exist in the first place.
- One vendor who served multifamily buildings asserted that the inclusion of water-saving measures made the ability to pay water and sewer bills very important to landlords and property managers.
- Echoing end-users and landlords, the only negative impact mentioned was reduced light quality tied to CFLs, and even this one vendor called it a “double-edged sword”

because participants typically like fixtures and brighter bulbs in the kitchen, but disliked the quality of light for other applications.

- A vendor who argued that the programs boost a home's value called out the addition of the "home energy score" in support of this benefit.

Table 62: Vendor Perspectives on Non-Energy Impacts

Number of responses	Mention to Participants	Personally Believe Participants Will Experience	Participants seem to Value[1]
Comfort	13	11	X
Home health and safety	11	6	X
Home value / appearance or the ability to sell the home	5	2	X
Outside Noise	4	2	
Equipment maintenance and/or durability	4	1	
Ability to pay non-energy bills such as water or sewer	3	2	X
Appliance or heating/cooling system noise	2	1	
Family illnesses and missed days from work or school and associated medical care	2	0	
Light quality	1	1	X
Environmental benefits / climate change	1	1	X
Avoid ice dams	1	1	

[1] As this question came at the very end of the survey, fewer than one-half of the 16 vendors provided an answer. Therefore, the table includes only an indicator of those mentioned by any vendors and not counts of how many respondents mentioned them.

6.6 Benchmarking – Non-Energy Impacts

The study benchmarked its results against two Northeast program evaluations that had been conducted relatively recently and were comparable in methodology. The first study evaluated a low-income program in Rhode Island (RI) that is similar to the Connecticut HES-IE program, and the second evaluated numerous programs offered by MA program administrators to both low-income and NLI customers. A third study was also examined, which dates back to 2005; it estimated an NEI rate, using a methodology similar to that used for the R4 study, for the NY HPwES program. Table 63 compares the results.

Connecticut HES-IE participants (62%) were just as likely as their counterparts in RI (61%) to experience positive impacts on their comfort resulting from the program. When it came to their ability to pay energy bills, HES-IE participants (48%) were less likely than their counterparts in RI (62%) to report a positive impact.[126]

The percentages of HES and HES-IE participants reporting that the program had a positive impact on other elements were lower than participants in the MA programs, although the differences were negligible for low-income participants' comfort. An important difference between the studies, however, was that the MA study only asked about specific NEIs (e.g., comfort or property value) for deeper retrofit measures such as new HVAC systems and/or insulation, while the R4 study focused more broadly on the impact of the HES/HES-IE program, asking all respondents about all NEIs.

When asked to compare the combined value of the NEIs to the expected energy savings, Connecticut HES and HES-IE participants valued program NEIs considerably more than their MA peers and somewhat less than NY HPwES participants: Connecticut HES (87% of energy savings) and HES-IE (90%) reported that the NEIs were a little less than expected energy savings, whereas MA NLI participants estimated NEIs equal to about three-quarters, MA low-income participants estimated NEIs equal to just over one-half of their expected savings, and NY HPwES participants estimated NEIs equal to expected energy savings.[127]

[126] This difference may be indicative of differences in changes in energy billing rates rather than the efficacy of program improvements.
[127] Note that the R4 survey asked participants to compare NEIs to an undefined bill savings amount while the MA analysis compared them to a defined dollar value. Additionally, the two studies did not ask about the exact same NEIs.

Table 63: Non-Energy Impacts Results – Benchmarking

Benchmarking Parameter	Comparison Program		Connecticut Value	Notes / Considerations
	Program	Value		
Percentage experiencing positive impacts – Low-income/HES-IE				
Comfort	Rhode Island (RI) Income Eligible[1]	61%	62%	None
	MA Cross-cutting[2]	65%		The MA study asks about *thermal* comfort specifically.
Ability to pay energy	RI Income Eligible	62%	48%	None
Property value or ability to sell	MA Cross-cutting	57%	30%	For both, the base is only homeowners (not renters).
Quality of lighting	MA Cross-cutting	68%	59%	The MA study also asks about lifetime in addition to quality.
Percentage experiencing positive impacts – NLI/HES				
Property value or ability to sell	MA Cross-cutting	80%	35%	See above.
Comfort		76%	63%	
Maintenance and/or durability		73%	37%	
Quality of lighting		70%	49%	
Value of NEIs as percentage of bill savings				
NLI/HES	MA Cross-cutting	77%	87%	None
Low-income/HES-IE		52%	90%	
HPwES/HES	NYSERDA HPwES[3]	100%	92%	

[1] Cadmus. *National Grid Rhode Island: Income Eligible Services Process Evaluation*. October 1, 2014.
[2] NMR. *Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation*. Prepared for Massachusetts Program Administrators. August 15, 2011.
[3] NYSERDA. *New York Energy Smart Program Evaluation and Status Report*. May 2005.

7 Section 7 Health and Safety Findings

The study asked participating HES/HES-IE end-users, HES-IE landlords and property managers, and HES vendors about the home health and safety issues that vendors have found during the home energy assessments. The respondents also addressed the implications that health and safety problems have on moving projects forward and the remediation steps that at least some participants take to resolve the issues in order to install energy-efficient measures. CATI surveys also asked nonparticipating occupants if they have discovered any health and safety issues in their homes to use as a baseline for comparison purposes. Four key themes emerged:

- From the vendor perspective, health and safety issues often prevent projects from moving forward.
- Comparisons between participants (who learned about health and safety issues during the assessment) and nonparticipants (who knew of the issues on their own) offered results that varied by income.
    - Low-income: HES-IE participants more frequently learned about health and safety issues via the assessment compared to income-eligible nonparticipants, who had prior knowledge about the same issues.
    - NLI: In contrast, HES participants were somewhat more likely to have learned about health and safety issues during assessments compared to nonparticipants in the same income category who had learned of such issues on their own.
- Participating end-users were more likely to learn that they have asbestos insulation from the vendors than were nonparticipating end-users to discover this on their own.
- Remediation costs act as a barrier to having asbestos fixed, therefore preventing the full assessment from taking place.

7.1 End-user Participant Surveys – Health and Safety

➢ ***Vendors discover asbestos and vermiculite insulation and knob and tube wiring; participant remediation is hindered by cost.***

Ten percent of HES and 22% of HES-IE end-user participants reported that the program vendors discovered at least one health and safety issue that kept vendors from completing the full assessment. Asbestos issues were most commonly mentioned in both programs (4% of HES and 8% of HES-IE); HES-IE participants also noted mold (6%), vermiculite insulation (4%), and knob and tube wiring (4%) rather frequently. As shown in Table 64, when it came to remediation, similar patterns occurred among the two programs, with participants most likely to respond to gas (typically repaired by the natural gas companies, who are HES and HES-IE program administrators) and carbon monoxide leaks and least likely to remedy asbestos and vermiculite insulation. While only a few of them did not address the issues, participants had varied reasons for not doing so, such as indicating that the projects would be too costly, remediation was unnecessary, or they simply had not "gotten around to it" (Table 96 in Appendix A.6.1).

Table 64: End-user Participant Survey Respondents – Health and Safety Issues Found and Rates of Remediation

Health or Safety Issue	Percentage with Issue Found		Percentage with Issue Fixed[1]	
	HES (n=433)	HES-IE (n=400)	HES (n=49)	HES-IE (n=90)
Gas leak	2%	2%	100%	100%
Carbon monoxide leak	1%	2%	100%	78%
Radon	1%	1%	50%	40%
Asbestos	4%	8%	37%	13%
Vermiculite	1%	4%	14%	21%
Mold	1%	6%	80%	41%
Knob and tube wiring	-	4%	-	31%
Other	3%	4%	64%	50%

Note: Responses are weighted.
[1] Sample sizes vary based on the base number of respondents that reported the issue being discovered by vendors.

7.2 End-user Nonparticipant Surveys – Health and Safety

➢ ***Nonparticipants discover issues on their own—primarily issues with mold.***

NLI nonparticipant customers (16%) had more often discovered health and safety issues on their own than their HES counterparts had discovered during program assessments (10%). Conversely, low-income nonparticipant customers (19%) were less likely to have had health and safety issues discovered outside of the program than their HES-IE counterparts (22%). Put another way, the programs tend to help low-income households identify health and safety issues more than they help other households.[128] As shown in Table 65, nonparticipants often discovered mold (13%). This is unlike program participants, however, who were more likely to learn that they had asbestos insulation. While nonparticipants were fairly likely to address issues, aside from vermiculite and knob and tube wiring, they expressed the same reasons as participants for not remedying health and safety issues: the cost and not having gotten around to it (Table 97 in Appendix A.6.1).

[128] This indicates a non-energy benefit of the programs, as addressed in Section 6.

Table 65: End-user Nonparticipant Survey Respondents – Health and Safety Issues Found and Rate of Remediation

Health or Safety Issue	Percentage with Issue Found		Percentage with Issue Fixed[1]	
	Non-Low-Income (n=140)	Low-income (n=100)	Non-Low-Income (n=23)	Low-income (n=19)
Gas leak	-	1%	n/a	100%
Carbon monoxide leak	1%	-	100%	n/a
Radon	3%	1%	75%	100%
Asbestos	2%	-	-	n/a
Vermiculite	3%	5%	67%	29%
Mold	12%	13%	72%	79%
Knob and tube wiring	1%	2%	-	67%

Note: Responses are weighted.
[1] Sample sizes vary based on the base number of respondents that reported the issue being discovered.

7.3 HES-IE Landlord and Property Manager Interviews – Health and Safety

➢ ***Health and safety issues were found but remediated without causing major program implementation delays.***

Five of the 30 landlord and property manager interviewees said that vendors identified health or safety problems during the energy assessment at only one of the five properties, thus delaying the initial assessment until maintenance staff had remediated the problem. All problems were resolved and did not cause extensive delays (additional details in Table 119 in Appendix B.2.4).

7.4 HES Vendor Interviews – Health and Safety

Participant surveys and interviews did not illustrate the extent to which health and safety issues prevent projects from ultimately taking place. The main obstacle that vendors need to navigate around is the health and safety issues they often face when conducting the assessment. The discovery of mold, asbestos, knob and tube wiring, vermiculite insulation, gas leaks, etc., frequently force technicians to halt the assessment because some core measures cannot be installed until the issues are remediated. Vendors estimated that health and safety issues occur in roughly one-quarter of all jobs (with estimates ranging between 5% and 40%).

8 Section 8 Connecticut Contractor Development

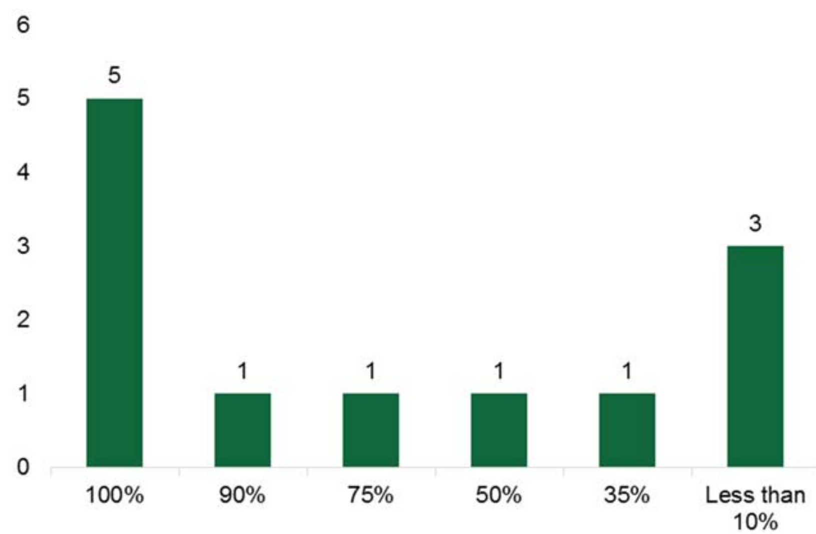
The study asked vendor interviewees about the growth of the industry and development of contractors' businesses and practices in the state they have seen from the HES/HES-IE program. Interviewees included 16 HES vendors who served the program in 2014.[129] Questions focused primarily on the impact of HES on their businesses and, to some extent, the impact on the market overall.

8.1 Direct Program Impact on Vendors' Businesses

- ***Vendors fall into two types: those who rely almost exclusively on HES for their work and those for whom HES supplements their work.***

When asked to provide an estimate of how much of their work is HES-related, seven of the 12 vendors answering the question said 75% to 100%, while five said 50% or less (Figure 55). Breaking this down shows even more bifurcation: five of the vendors said 100% of their work comes from HES, but three said less than 10% of their work did. This last group includes one vendor who served HES in 2014 but was not selected to continue with the program in 2015,[130] and a second vendor who had actively reduced their involvement in HES due to associated increased "administrative costs" of working with the program.

Figure 55: HES Vendor Interviewees – Percentage of Work from HES
(Count of responses)



[129] However, not every vendor had time or could answer each of the questions in this section.
[130] The vendor provided fair and reasoned responses on their 2014 involvement with HES and continues to work with the Companies on other programs (to say more would breach confidentiality). Therefore, despite no longer serving HES, the analysis includes the vendor's responses from this interview.

- ***Viability of vendors' businesses largely depends on the existence of HES.***

Being extremely careful to stress that the scenario was completely hypothetical, interviewers asked vendors to assess the impact of the closing of HES on their business. Most vendors explained that it would have a large negative impact. Some argued that not only would they have to close their businesses, but also that the entire industry would collapse:

I basically would just shut down shop, give up, and do something else.

Right now, the market is not ready to really have any type of robust energy-efficiency industry without a subsidized program.

I think if the program did go away, we wouldn't have an industry, and we would lose everything that we've worked for to this point.

Others argued that their businesses would survive, but they predicted revenue decreases of 60% to 80%. Only the few vendors who already have substantial non-HES work felt that stopping the program would have little impact on their work.

- ***Vendors report that the program has led to increased staffing and revenue levels.***

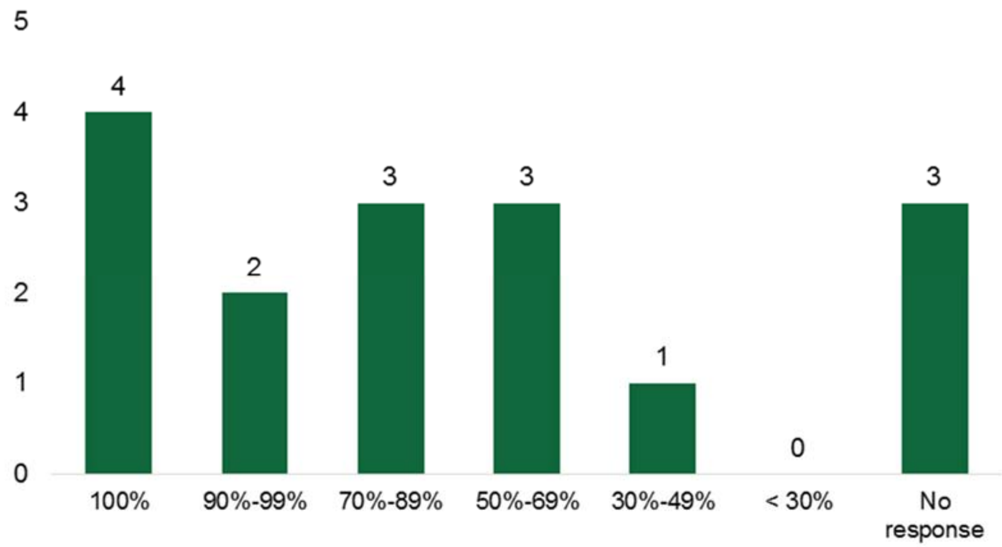
Interviews asked vendors about the program's impact on their staffing and revenue:

- **Staffing levels**. Many vendors reported that their staff levels had at least doubled since they started working with HES; five said they had increased staffing by more than 500%, although the initial staffing levels often were quite small (e.g., only two staff members). Vendors generally attributed these increases to their partnership with the program. Others argued that their staffing levels vary with their workload, with two in this group directly tying the fluctuations to HES budgets and program "constraints." One of these two vendors clarified that the program's "tightening" of rules around the vendor's measure recommendations and the "push for gas" have negatively affected their HES business, causing the vendor to lay off people they had initially hired for program work.
- **Revenue.** Likewise, 10 of the 16 vendors reported that their revenue had increased since joining HES. However, four explained that their revenue initially went up and then went down, while two others said their revenue had not really changed. Vendors attributed at least 50% of the revenue increase directly to HES work, with only one reporting that revenue was less than 50% and three others choosing not to answer (Figure 56).[131] HES participants, however, rarely turn to the vendors to perform additional non-HES work. Ten of the 13 vendors answering this question said less than 10% of their work comes from HES participants who hire them for non-HES services following HES participation, but some vendors were quick to point out that this reflects their decision to focus their business solely on providing HES services. The other three vendors responding said 10% to 29% of their non-HES work stemmed from former HES customers.

[131] None of the four vendors citing less than 50% or who chose not to answer was the vendor no longer providing HES services.

Figure 56: HES Vendor Interviewees – Percentage of Revenue Increase from HES

(Count of responses)



8.2 Impact of HES on Energy Service Industry

- ***Vendors believe HES has helped expand their energy efficiency business and the general market for energy efficiency services, but they are more uncertain about the continued HES-induced growth of the industry.***

Vendors also rated their agreement with four statements about the current and future impact of HES on the market for energy efficiency services, using a zero-to-ten scale, where zero was "strongly disagree" and ten was "strongly agree." The four questions read as follows:

> "I think that the program actually creates the marketplace."
>
> *– HES vendor*

1. There is more business for your company than there would have been without the program.
2. There is more business in general in the marketplace than there would have been without the program.
3. There will be more business for your company than there would have been without the program.
4. There will be more business in general in the marketplace than there would have been without the program.

Every vendor agreed (with a rating of six or higher) that HES has increased the amount of work available for their business; the mean was 9.5 (Figure 57). They also generally agreed that HES has positively impacted the energy services market in general; every vendor again provided a rating of six or higher, but the mean response of 8.4 was lower than for direct vendor impact.

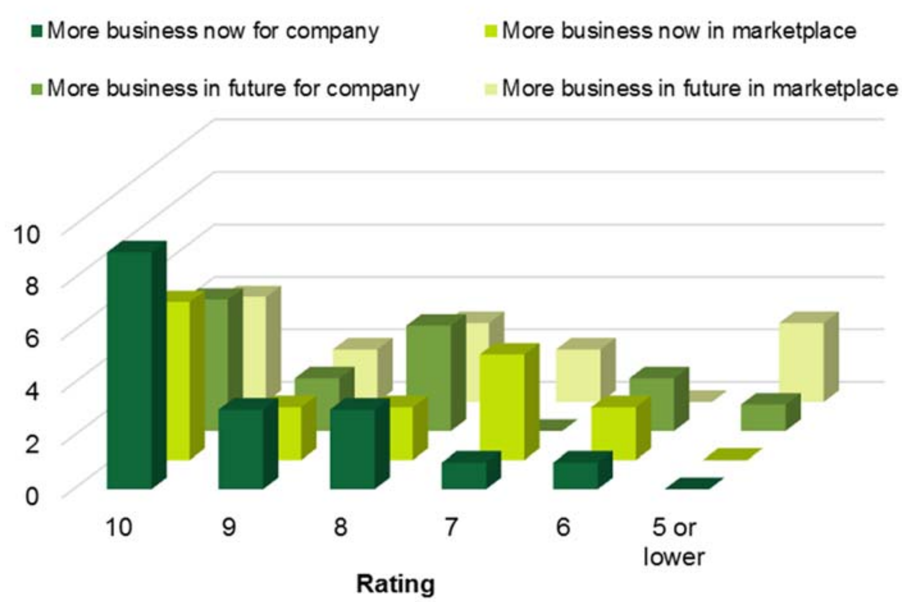
I have seen other companies not linked directly with the program directly benefit through referrals.

Some vendors, however, did voice concerns about the rules and requirements to be a program-approved contractor. Some also said they perceived greater allocation of program funds to core services as opposed to the deeper measures, which they thought were barriers to HES having a greater impact on the marketplace in general.

Vendors held a wider range of opinions about the future impact of HES on the amount of work for their business and the marketplace, and the mean ratings were 7.9 and 7.4, respectively. The greater uncertainty about the future impact of the program centered on the program "rules," such as the test results for recommending measures and the measures rebated by the program. As one vendor explained, "If things stay the same, and they don't change or tighten rules, I would say eight or nine." Another vendor pointed out that, while not there yet, if the market were to become saturated, business would decrease for all vendors.

Figure 57: HES Vendor Interviewees – Degree to which HES Has Affected/Will Affect Amount of Business

(Count of responses)



Note: Responses are on a scale of zero to ten, where zero is "strongly disagree" and ten is "strongly agree."

8.3 Benchmarking – Connecticut Contractor Development

The benchmarking of the contractor development compared the results of this study with those of the Better Buildings Neighborhood Program (BBNP)[132] market effects study. The

[132] Sponsored by the U.S. Department of Energy, BBNP provided three-year funding to 41 state and local governments to support programs promoting whole-building energy upgrades.

BBNP study asked the same set of scale questions of participating program contractors as this Connecticut HES study asked its program vendors, offering a point of comparison despite a number of caveats in program structure and study focus when comparing the studies and programs.[133] Due to these caveats, the reader should interpret these results with caution. Percentages of vendors agreeing with the statements related to Connecticut HES were considerably higher than those ratings for BBNP. As with the BBNP study, this Connecticut study shows a decrease in the expectations for impacts on the market in the next two years. However, the decreases in expected changes in the market in the next two years were notably larger for the Connecticut vendors compared to the BBNP contractors—possibly reflecting vendors' concerns about the future of the program, but also higher initial values and hence more potential for a decrease.

Table 66: Connecticut Contractor Development – Benchmarking

Benchmarking Parameter	Comparison Program		Connecticut HES Value	Notes / Considerations
	Program	Value		
Staff increases				
Percentage of program vendors reporting staff increases attributable to the program	Better Buildings Neighbor-hood Program (BBNP)[1]	43%	60%	BBNP percentages includes commercial contractors (29 of 147 contractors)
Agreement Scales (percentage of vendors rating 7 to 10)				
Impact program has had on my company	BBNP	58%	94%	This analysis excluded commercial contacts from BBNP results so percentages in this table do not appear in the original BBNP report
Impact program will have on my company		51%	79%	
Impact program has had on the market generally		58%	88%	
Impact program will have on the market generally		52%	79%	

[1] Research into Action, Inc. and NMR. *Market Effects of the Better Buildings Neighborhood Program: Volume 5*. February 2015.
Note: The differences in sample sizes between this study (n=15 vendors) and the BBNP study (n=147 vendors) is quite large.

[133] BBNP grantees did not necessarily carry the same program structure or same type of implementers as the Connecticut HES program – however, all were retrofit programs, and many were home energy assessment-based programs that sought to encourage additional upgrades through use of rebates and financing. Grantees were distributed throughout the U.S., but nearly one-fifth of them were located in the Northeast. Additionally, this R4 study did not measure market effects specifically, but was assessing the extent to which the program has impacted the development of contractors in the state.

9 Section 9 Connecticut Clean Energy Communities (R152) Findings

Findings from the Clean Energy Communities task (R152) were split into two subsections: themes that emerged from the in-depth interviews with utility staff and leaders of energy-related community groups, and results of the data analysis.

9.1 Findings From the CEC Interviews

Findings from the in-depth interview portion of this task have been split into three segments: 1) observations about the characteristics and behaviors associated with successful CEC engagement, 2) common responses from community leaders in regard to driving HES participation through the CEC program, and 3) community leader recommendations for improving the CEC program.

9.1.1 Successful Community Characteristics

The first theme that emerged from the in-depth interviews is that successful community engagement in the CEC program is driven by a core group of highly motivated individuals within that community. One community leader respondent said that the key to program success is "identifying a small group of passionate people who are willing to work long and hard together." The identification of a small group of dedicated individuals can be a strength; however, relying on a small group can also be a weakness. A different community leader mentioned that their community had previously had one community member who was responsible for much of the impetus for that town's engagement with the program but, after that person left the town, engagement with the program ceased for a few years. Activity only restarted when a new cadre of motivated community members re-engaged with the program. All of the communities identified as successful in the CEC program have now formalized their core group through the creation of a town taskforce or committee rather than simply being a group of interested individuals acting on their own. By creating such a body, the loss of a key individual does not remove the position that person held, and thus creates some stability in the community's engagement with the program.

A second theme common to the interviews is that piggy-backing on other community events in order to engage the public in the CEC program (and energy efficiency and clean energy in general) served as a successful strategy for community outreach and education. Such occasions include town fairs, celebrations on community greens, back-to-school events, and the like. By joining existing events, the CEC reached community members who may not otherwise have engaged with energy-related issues. As one respondent said, "People come to get their kids' faces painted and leave with information on insulation and lighting efficiency." Interviewees also noted, however, that capturing the attention of people in the community who are not self-motivated about energy efficiency remained one of the challenges for CEC, leading some to stress the importance of managing expectations for this kind of community engagement. For example, one respondent voiced frustration about having to compete with the cupcake booth located next to their table of fliers on energy efficiency.

A final theme common to all the interviews was the importance of the utility staff in executing the program. The utility staff were clearly proud of their efforts to be accessible and responsive to community members, and this was reflected by community member recognition of the efforts and effectiveness of the utilities' program staff. Several of the community respondents appreciated the utilities' efforts to assist in outreach and partner with the town or town energy committee. Due to the uniform praise regarding the accessibility of the utility program staff, towns seeking to increase their program engagement should be encouraged to communicate with the utility staff members to develop a strong relationship between the town's energy taskforce and the CEC utility program staff. Community members should invite utility staff to meetings and events, ask their advice on the most effective strategies for encouraging adoption of energy conservation (and renewable energy) behavior, and brainstorm creative ways to engage community members who may have little interest in energy-related issues.

9.1.2 Relationship between CEC and HES

Community leaders' responses were mixed regarding the extent to which the CEC program drives HES program participation. Several community leaders expressed disappointment at the low levels of HES uptake in their communities, even in communities that have relatively high levels of HES uptake compared to the rest of the state. As one respondent said, "People who are already interested in [energy efficiency] are already aware of the program, but we're not sure how to reach those not interested." Another respondent suggested that working with specific contractors could be an asset for program outreach; however, it is not appropriate for most towns to recommend specific contractors. A third respondent identified having a high proportion of renters as an additional challenge associated with encouraging HES participation in a community, saying that they were still searching for a way to better engage landlords and property managers. One community found that giving away HES home assessments as prizes at a community event (that is, paying the HES assessment co-pay) was an effective way to raise awareness and interest in the program, and that doing so seemed to encourage people to sign up for the program. The CEC program was praised for the way in which points are accumulated for participation in HES and other programs as well as deeper measure update; one respondent likened this approach to frequent flier miles or credit card points and thought this was a useful way to simplify targets and encourage success. When they accumulate 100 points, the towns become eligible to apply for grants of $5,000 to $15,000 to fund energy-efficiency initiatives.

9.1.3 Suggested Improvements to CEC

Responses from community leaders regarding how the CEC program could be improved fell into two related categories. First, community leaders suggested that more structure would be beneficial to the program. One respondent said that it was "empowering that the taskforce decided how and what to do, but a more standardized framework would be helpful." Respondents indicated that it would be useful if they were given some guidance or recommendation of what activities they can take and how to accomplish them. The second category related to simplifying the program. The respondents were glad that multiple energy efficiency programs are available, and they understood that each of these programs evolve to reflect changing circumstances and program goals. However, the frequent changes and evolution made it difficult for the volunteer committees to keep up to date with all of the relevant program details.

9.2 Findings From CEC Data Analysis

This section describes the findings of the data analysis, progressing from the simplest measures of statistical association toward an analysis that controls for additional factors which may influence that association. There are two questions that are tested in this section: first, if measure of utility outreach to communities is associated with greater community CEC point accumulation and, second, whether utility outreach is associated with higher community HES deep-measure uptake. The findings are that there is a relatively weak association between outreach and point accumulation, once other community factors that are associated with point accumulation are controlled for, and that there is not a statistically detectable consistent relationship between utility outreach and deep-measure uptake. A more detailed description of this work follows.

Data on outreach activities by utility staff were used to group towns based on the intensity of the outreach received. The estimated number of utility interactions for each town was normalized by the town's size (using household counts, as reported by the CEC dashboard) to generate normalized town outreach rates. Towns were then grouped by quartile of these normalized outreach rates. The resulting quartiles are not uniform in terms of town counts due to a clustering of towns at the lower bound (i.e., those with no outreach events). These town quartile groups were used to test for independence[134] between the groups using points accumulated, as reported on the CEC dashboard, as an outcome of interest. This was done for both total residential points (program and rebate points summed) and total town efficiency points, which include municipal and small business activities as well.[135]

9.2.1 Chi-Squared Test

- ***Participation in CEEF-funded residential, municipal, and small business programs varies by level of CEC program activity, as measured by the program point system.***

This subsection reports results of a chi-squared test of the association between utility outreach and CEC point accumulation. Table 67 reports the values and results of the chi-squared tests of group independence. The town quartile columns are the groupings of towns based on the normalized utility outreach activities. The points achieved under the CEC program are listed for all CEC activities in the left-hand tables and for residential activities only in the right-hand tables. The "expected points" columns indicate the number

[134] In this context, independence means that membership in one group is not associated with a different point accumulation compared to the other groups.
[135] Recall that towns that earn 100 points are eligible to apply for grants of $5,000 to $15,000 to fund energy-efficiency initiatives. http://www.energizect.com/your-town/solutions-list/clean-energy-communities

of points that would be expected of that quartile given the number of towns and an assumption that there is no relationship between the quartiles and point accumulation. The two top tables show results of all points accumulated in the CEC program to date, while the bottom two tables show results only for the same period as the outreach data that were available from the utility staff. The tests indicate there is a statistically significant relationship (*p* < 0.1) between membership in the town quartiles and points accumulated for each of the four points measures tested.

Table 67: CEC Outreach Chi-Squared Test Results

	Total CEC Points					Residential Only Points				
	Town Utility Outreach Quartile	Achieved Points	Town Count	Expected Points		Town Utility Outreach Quartile	Achieved Points	Town Count	Expected Points	
All points accumulated through October, 2015	1 (highest)	7,206	41	6,239		1 (highest)	4,748	41	3,979	
	2	6,295	39	5,935		2	3,736	39	3,785	
	3	3,364	20	3,043		3	2,248	20	1,941	
	4 (lowest)	8,852	69	10,500		4 (lowest)	5,668	69	6,696	
	Total	25,717	169	25,717	χ^2, $p < .001$	Total	16,400	169	16,400	χ^2, $p < .001$
	Town Utility Outreach Quartile	Achieved Points	Town Count	Expected Points		Town Utility Outreach Quartile	Achieved Points	Town Count	Expected Points	
Points accumulated 2012 through October, 2015	1 (highest)	4,678	41	4,082		1 (highest)	2,816	41	2,481	
	2	4,199	39	3,883		2	2,416	39	2,360	
	3	2,246	20	1,991		3	1,494	20	1,210	
	4 (lowest)	5,704	69	6,870		4 (lowest)	3,500	69	4,175	
	Total	16,827	169	16,827	χ^2, $p < .001$	Total	10,226	169	10,226	χ^2, $p < .001$

9.2.2 ANOVA Test

This subsection reports additional findings of the relationship between utility outreach and CEC point accumulation. Table 68 shows the results of a series of analysis of variance (ANOVA) tests in which the annual normalized outreach quartile groups are tested for joint significance (*F* statistic) as predictors of total points accumulated in each year (left-hand table) and as predictors of the percent of households in a town that are new participants in the HES program (right-hand table). This test was selected in order to identify the years in which the utility outreach grouping is, jointly, associated with each outcome. Statistical significance in these tests is shown with *p*-values less than 0.1. These ANOVA tests indicate a statistically significant relationship at the 90% confidence level between normalized outreach quartile and CEC points in 2013, 2014, and 2015 and between normalized outreach quartile and new household participation in 2013 and 2015.

Table 68: CEC Outreach ANOVA Test Results, Annual

	New Points per Year			New Household Participation per Year		
Year	*F* stat	df	*p* value	*F* stat	df	*p* value
2012	0.46	1	0.5003	0.21	1	0.6458
2013	**19.32***	1	<0.0001	**8.43***	1	0.0042
2014	**6.47***	2	0.0020	1.52	2	0.2228
2015	**9.61***	2	0.0001	**4.20***	2	0.0167

* Indicates significance at 90% confidence level

The results shown in Table 67 and Table 68 suggest a relationship between the level of town outreach and CEC outcomes. However, these simple analyses do not prove a causal relationship. Instead, other factors such as social, economic, or demographic characteristics of town residents could be driving the results. Therefore, the study turned to ordinary least squares regression to tease out impacts of the program after controlling for some of these other factors.

9.2.3 Ordinary Least Squares Regression

This subsection reports a final set of measures of association between utility outreach and CEC point accumulation as well as findings of the association between utility outreach and HES deep-measure uptake rates. Table 69 presents the results of a series of regression models that tested for the relationship between normalized town outreach and the accumulated points in each prior program year,[136] while controlling for median town income and the percentage of renters in the town. Compared to the chi-squared and ANOVA analyses, the analysis suggests a much weaker relationship between outreach activity and CEC points earned by households in a community in a given year, as indicated by the coefficient estimates for normalized interactions, after controlling for other factors. Only 2014 shows a statistically significant effect of outreach once these additional controls are included.

[136] The inclusion of this variable recognizes that some communities are more "green" in their outlook than others, and this "greenness" could also be driving participation in CEEF programs. Controlling for prior points, therefore, controls for this possible characteristic and allows the model to isolate the annual effect of outreach on the points gained in a single year.

Table 69: CEC Outreach Regression Results

Predictor Variable	Coefficient Estimate (Standard Error)			
	2012	2013	2014	2015
Cumulative Points (t-1)	**0.105***	**0.075***	**0.131***	**0.084***
	(0.045)	(0.030)	(0.022)	(0.017)
Median Income	0.739	0.345	**0.714***	0.038
	(0.470)	(0.398)	(0.330)	(0.305)
Rental %	**0.244***	**0.135***	**0.158***	-0.041
	(0.096)	0.081	(0.068)	(0.063)
Normalized Utility Outreach (t)	-3.263	-0.302	**9.100***	3.678
	(32.477)	(2.660)	(3.504)	(6.499)
Constant	0.276	4.091	-1.106	**6.796***
	(5.575)	(4.678)	(3.878)	(3.548)
R^2	0.075	0.061	0.288	0.147

Dependent variable is points earned in year (t).
* Indicates significance at 90% confidence level

A final set of tests performed was an examination of the association between CEC outreach and the uptake of deeper HES measures. Table 70 shows the results of these multivariate regressions in which the dependent variable in each column is a different deep HES measure category, normalized to town population. The table reflects results from 2014, which is the only complete year for which deeper HES measure data were available for both Companies. As the table shows, the only significant relationships between outreach and deeper HES uptake are for heat pumps and air conditioning—and the results are in the wrong direction, suggesting that outreach is associated with lower uptake of these two measures. Lacking a theoretic explanation for the inverse relationship between uptake of these measures and CEC outreach, combined with the relatively poor explanatory power of the models (R^2), it is likely that this finding is spurious. That is, the finding of a reduction in deeper-measure uptake as a function of utility outreach is probably an aberration rather than a meaningful result. However, the results do suggest that there is no consistent relationship between outreach and uptake of these individual measures.

Table 70: CEC Outreach Association with HES Deep-Measure Uptake, 2014

Predictor Variable	Coefficient Estimate (Standard Error)				
	Insulation	Furnace/Boiler	Heat Pump	Air Conditioning	Windows
Normalized Utility Outreach	0.0007	-0.0008	**-0.0046***	**-0.0013***	-0.0002
	(0.0007)	(0.0005)	(0.0013)	(0.0006)	(0.0002)
Median Income	**0.0003***	**<0.0001***	**-0.0002***	**0.0002***	<0.0001
	(<0.0001)	(<0.0001)	(0.0001)	(<0.0001)	(<0.0001)
Rental %	**>-0.0001***	<0.0001	**-0.0001***	>-0.0001	>-0.0001
	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)
Constant	0.0004	<0.0001	**0.0092***	-0.0001	0.0005
	0.0007	<0.0001	(0.0015)	(0.0007)	(0.0002)
R^2	0.318	0.039	0.183	0.185	0.025

* Indicates significance at 90% confidence

10

Section 10 Document Review Findings

The document review assessed the materials and resources that Energize Connecticut and the utilities provide in support of the HES and HES-IE programs, and whether those materials and resources are effective, clear, engaging, consistent and accessible to potential program participants and vendors. The analysis indicates that the participation and financing materials and vendor documentation tools offered are generally clear and effective resources for customers and vendors to utilize. The document review also helped to clarify whether any existing materials or resources currently support the evaluation's recommendations. The program provides many resources to meet customer and vendor needs. Table 71 summarizes the program recommendations and discusses them in light of existing materials and resources.

Table 71: Evaluation Recommendations – Relationship with Program Document Review Findings

#	Recommendation Description	Audience	Documentation Review Findings
Process Recommendations			
#4	Participants recommend increased advertising; consider new/additional opportunities with vendors to conduct co-op advertising for HES/HES-IE	Customers	The document analysis did not find evidence of co-op advertising.
#5	Future advertising should continue to communicate the value of the program, emphasizing energy and energy cost savings; address customer skepticism about need for improvements or "I haven't gotten around to it" attitudes	Customers	The program provides a great deal of advertising using a variety of mediums, but it does not appear to underscore the *necessity* of making the improvements and “act fast” language.
Financing and Decision Making Recommendations			
#7	Provide vendors with additional or more detailed talking points/materials to encourage add-on measure upgrades	Vendors	The document review findings indicate that the program provides extensive print and online materials to support customers and vendors, but survey and interview findings indicate that additional details about program offerings may be needed to address customer concerns about information quality. Short-term survey respondents are significantly more satisfied with information quality than long-term respondents, possibly signaling program improvements or superior recall due to more recent participation.
#8	Clarify program processes and offerings further for customers who are concerned about information quality	Customers	
#11	Provide "everyday" language version of loan applications	Customers	The program's online financing tool already provides a great deal of assistance to customers, but the other evaluation efforts indicate that customers and vendors need clearer and/or further guidance.
#12	Expand on materials that provide financing information	Customers	
#13	Provide vendors with additional talking points/sales methods to address initial customer attitudes rejecting the idea of applying for loans	Vendors	The Implementation Manual asks vendors to direct customers to the Energize Connecticut website for more information about financing options, but does not encourage them to explain the options in detail to better ensure that that the customer understands the options and how best to take advantage of them.
#14	Provide guidance to vendors about preferred language to use when referring to financing	Vendors	

#	Recommendation Description	Audience	Documentation Review Findings
NEI Recommendations			
#21	Communicate the value of the program through greater emphasis on NEIs in program materials	Customers	Program messaging does not actively highlight NEIs such as improved comfort and safety, which can be major motivators for participation.
Health and Safety Recommendations			
#23	Provide more information on the financing options that cover at least part of the costs of remediating health and safety issues.	Customers	Current program materials do not suggest financing options for health and safety remediation.

Note: Evaluation recommendations can be found in greater detail in the Executive Summary of this report.

As noted above, the document review included the customer-facing and vendor-facing resources and materials that the Companies provided, as well as the program website. Table 72 links commonly used documents with their target audiences and the program areas they support. Refer to Sections 10.1 through 10.4 for further details about these documents.

Table 72: Program Documentation Included in Document Review

Resources/Materials	Target Audience		Related Program Areas		
	Customers	Vendors	Process	Financing	Decision making
Energize Connecticut website	x		x	x	
Energize Connecticut Online Loan Tool	x			x	
POD Booklet	x			x	
HES Home Energy Report	x		x		x
Financing Chart		x		x	x
Rebate and Incentives Chart		x		x	x
Implementation Manual		x	x	x	x

10.1 Participation Resources and Materials

Program materials contain a significant amount of information about the assessment process that appears to be easy to understand from the customer perspective. In particular, the Energize Connecticut website and the HES Comprehensive Home Energy Report are relatively straightforward in their descriptions of program processes. The following is a more detailed description of key program resources and materials provided to end-users:

- **The Energize Connecticut website** is straightforward and should be easy for customers to use to find information on particular areas of interest, such as contractors to work with or rebates to apply for. It is also clear and easy to figure out how to schedule an assessment as well as find out which services are offered.
- **The HES Comprehensive Home Energy Report** is customer-facing and explains exactly what should take place during the assessment in clear language; it is not overly technical or written in language that might be confusing. The Recommendations pages in this Packet could be difficult for customers to understand, but it is assumed it would be covered in person by the vendor during the kitchen table wrap-up.

10.2 Vendor Tools and Materials

The program produces a number of materials and resources to support vendors as they work to educate customers about the assessment and program offerings. Overall, these resources appear to be clear and concise. Following is a more detailed description of key program tools offered to vendors.

- **The POD Booklet** is used by vendors when speaking with customers during the kitchen table wrap-up after the assessment. It provides information such as release forms, rebate applications, and an HES "checklist" that highlights the key areas to cover during the assessment.
- **The Implementation Manual** appears to be a useful resource for vendors as they help guide customers through the program. It instructs them to assist customers in filling out qualifying rebate forms and to discuss the rebate and incentive options with customers. It provides example language to use during this explanation for each type of offering. It also provides detailed instructions for vendors about how to discuss the results of the energy assessment with the customer and offers example language to use when explaining the results. It also includes language on how to make specific recommendations to the customer for further work in each area of efficiency covered by the assessment.

10.3 Financing Tools and Materials

The program produces a number of tools and materials to support customers as they learn about the financing options that are available to them. The Energize Connecticut website and its online financing tool as well as the POD Booklet provide a good deal of financing background information for customers. Vendors are provided with a chart of financing options, and the Implementation Manual instructs vendors to refer customers to the Energize Connecticut website to learn more about financing options. Following is a more detailed description of key financing tools and materials offered to end-users and vendors.

- **The Online Financing Tool** is housed on the Energize Connecticut website; it is a customer-facing interactive financing tool that is easy to find and helps customers learn about and apply for financing options online. The process may be somewhat confusing without talking with a specialist before filling out an application, but it appears to provide a good summary of information and description of the various options available to customers.
- **The Implementation Manual** asks vendors to direct customers to the Energize Connecticut website for more information about financing options, but does not encourage them to explain the options in detail to better ensure that that the customer understands the options and how best to take advantage of them.
- **The Financing Chart** provides a brief yet useful overview of individual loan types available to customers. The Implementation Manual does not mention this chart.
- **The POD Booklet** has two pages on financing. One contains a table listing the different loan programs and associated program improvements, and the second page has information on the Energy Conservation Loan Program. It is not clear if this is referring to one of the types of loans included in the first page, and if not, how it differs and why it is listed separately.

- **The HES Comprehensive Home Energy Report** includes, where applicable, a Financing page that details the loan recommended for the customer, estimated monthly payments associated with loan terms, the total estimated cost of the associated measure, the long-term savings, and a link to the Energize Connecticut webpage for the respective loan.

10.4 Marketing Materials

The program provides many different marketing materials to reach potential HES customers. An analysis of these materials indicates that there are several marketing channels used, including traditional means (e.g., newspapers, bill inserts, brochures, letters, television, and phone outreach), as well non-traditional means, such as paid advertisements on Pandora Radio and Facebook, and Google pay-per-click advertisements (Table 73). Based on the marketing materials provided, they appear to be clear and easy to understand. Despite these numerous activities, participants responding to the CATI survey recommended increasing advertising and the quality of information provided about the program.

Table 73: Marketing Mediums Used to Support HES and HES-IE Programs[1]

Medium	HES Specific	HES-IE Specific	General Energy Efficiency Messaging
TV			X
Radio (English and Spanish)	X	X	X
Google Pay-Per-Click	X	X	X
Pandora Radio			X
Digital Display Advertising	X	X	X
Transit: Bill boards			X
Transit: Bus			X
Transit: Metro North			X
Facebook advertising			X
Direct Mail	X	X	
Bill inserts	X	X	X
E-mail	X		X
Print ads, newspaper, Spanish only	X	X	
You Tube Advertising	X	X	X
Community Events	X	X	X
Door-to-door canvassing (done by trade allies with company supervision)	X	X	X
Point-of-purchase info		X	
Association advertising (Chambers, environmental group, AARP, neighborhood associations) in newsletters, directories, websites	X	X	X
Public Relations (formal energy efficiency campaigns, not just opportunistic)	X	X	X
Authorized contractors coop advertising	X	X	

[1] Source: HES Marketing_Jan_26_2015.docx
[2] 2015 marketing plans include an expansion of e-mail communications with HES-IE customer and door-to-door canvassing with HES customers.

A

Appendix A Additional Details

A.1 Methodology

A.1.1 End-user Participant Surveys

Table 74 presents the strata weights that the study used for analysis.

Table 74: Participant End-user Survey – Weights for Analysis by Study

Strata Group	Weight
R4 Strata	
HES – Core Only	1.66
HES – Insulation	0.66
HES – Other Add-ons	0.25
HES-IE – Core Only	0.92
HES-IE – Add-ons	1.11
HES-IE – Insulation	1.07
R31 Strata	
Core Only	1.70
Insulation	0.72
Other Add-ons	0.40
Rebate Only	0.50

Table 75: Participant End-user Survey – HES Sample Frame Development (R4)

HES Participants (July 2013 – December 2014)	Eversource	% of Total	UI	% of Total	Total
Original records provided (measure-level)	284,482	83%	60,217	17%	**344,699**
Original projects	20,443	84%	3,892	16%	**24,335**
Duplicate/incomplete/commercial contacts	1899	69%	851	31%	**2,750**
Unique contacts	18,544	86%	3,041	14%	**21,585**
% of original projects	91%		78%		
Contacts reserved for other studies	6,317	90%	720	10%	**7,037**
% of unique contacts	34%		24%		
No measures	101		63		**164**
Sample frame provided for R4	12,126	84%	2,258	16%	**14,384**
% of unique contacts	65%		74%		
Completed surveys	377	87%	56	13%	**433**
% of sample	3%		2%		

Table 76: Participant End-user Survey – HES-IE Sample Frame Development (R4)

HES-IE Participants (July 2013 – December 2014)	Eversource	% of Total	UI	% of Total	Total
Original records provided (measure-level)	187,323	88%	24,655	12%	**211,978**
Original HES-IE projects	5,931	67%	2,885	33%	**8,816**
Duplicate/incomplete contacts	347	68%	167	32%	**514**
No measures	13	27%	35	73%	**48**
Unique contacts	5,571	67%	2,683	33%	**8,254**
% of original HES projects	94%		93%		
Sample frame provided for R4	5,571	67%	2,683	33%	**8,254**
% of unique contacts	100%		100%		
Completed surveys	345	86%	56	14%	**401**
% of sample	6%		2%		

Table 77: End-user Participant Survey – Verified Sample Measures Compared to Population Measures

Measure	HES		HES-IE		Rebate-only	
	Population (n=26,762)	Sample (n=547)	Population (n=10,434)	Sample (n=525)	Population (n=815)	Sample (n=60)
Air Sealing	69%	53%	65%	54%	-	-
Duct Sealing	24%	15%	12%	5%	-	-
HVAC maintenance	-	-	6%	5%	-	-
Light Bulbs	93%	88%	87%	82%	-	-
Water Pipe Wrap	69%	41%	32%	20%	-	-
Lighting equipment	-	-	1%	< 1%	-	-
Water Saving Equip.	59%	45%	79%	63%	-	-
AC Equipment	2%	3%	-	-	30%	23%
Appliance (unspecified)	< 1%	< 1%	18%	3%	-	-
Clothes washer	< 1%	< 1%	-	-	-	-
Air Source Heat Pump	< 1%	< 1%	-	-	9%	8%
Ductless Heat Pump	3%	4%	-	-	45%	57%
Freezer	-	-	2%	3%	-	-
Geothermal Heat Pump	< 1%	1%	-	-	< 1%	3%
Heating Equipment	2%	4%	< 1%	< 1%	20%	13%
Water Heater	1%	2%	-	-	6%	
Refrigerator	< 1%	< 1%	14%	23%	-	-
Windows	2%	4%	1%	1%	-	-
Insulation	18%	26%	22%	20%	-	-

Note: Excludes some measures that represented very small portions of the population and were not included in the samples.

Table 78 includes more detail on the reasons that surveys were not completed for R4 and R31. For R4, no answer (30%) or pickup by an answering machine or voicemail (35%) were the most common reasons for non-response. These served as the second (24% no answer) and third

(14% answering machine) most common reasons for R31 non-response. The most common R31 reason for non-response was refusal to complete the survey (40%), which was the third most common reason for non-response among R4 respondents. The different rates of answering machines between the two surveys reflects that 1) the surveyors had more numbers to draw on for R4 than R31, and 2) more sample was released and called on to meet quotas toward the end of the surveys, but quotas were reached before these numbers could be dialed further to either turn them into completes or other dispositions.

Table 78: End-User Participant Survey – Reasons for Not Completing Survey

(Base = all phone numbers dialed at least once)

Reasons for not completing survey	Percent of Numbers Dialed	
	R4	R31
Phone Numbers Not Yielding Completed Survey	10,837	2,199
Non completed surveys	**15%**	**42%**
Mid-survey termination	<1%	2%
Household-level refusal	14%	40%
Not Contacted – Respondent never available	**7%**	**5%**
Other	**1%**	**2%**
Language problem	1%	2%
Miscellaneous	<1%	0%
Unknown Eligibility	**67%**	**39%**
Always busy	1%	0%
No answer	30%	24%
Answering machine	35%	14%
Call blocking	<1%	<1%
Not Eligible	**10%**	**13%**
Fax/data line	1%	<1%
Disconnected number	4%	4%
Number changed	3%	0%
Cell phone	<1%	0%
Business, government office, other organizations	1%	1%
No eligible respondent	1%	1%
Quota filled	<1%	6%

A.1.2 End-user Nonparticipant Surveys

Table 79: Nonparticipant End-user Survey – Sample Frame Development

HES Nonparticipants	Eversource	% of Total	UI	% of Total	Total
Original records received	3,400	68%	1,600	32%	**5,000**
Missing/invalid phone number	2	6%	32	94%	**34**
Commercial contact	238	81%	55	19%	**293**
Duplicate contact (phone, address, or contact name)	19	95%	1	5%	**20**
Participant sample contact	23	74%	8	26%	**31**
Final sample frame	***3,118***	***67%***	***1,504***	***33%***	***4,622***
% of original records in sample frame	92%		94%		

Table 80 includes more detail on the reasons that surveys were not completed for 20,546 of the R4 nonparticipant phone numbers called. Most commonly, the phone call was picked up by an answering machine (59%) or was not answered (14%). The third most common reason was that the respondent was never available (12%). The high rate of answering machines reflects the release of additional sample toward the end of calling in order to achieve desired quotas for low-income and NLI. The firm achieved its quotas before having the opportunity to redial answering machine-only numbers, so the numbers remained in that disposition.

Table 80: R4 Nonparticipant Survey – Reasons for Not Completing Survey

(Base = all phone numbers dialed at least once)

Reasons for not completing survey	Percent of Numbers Dialed
Phone Numbers Not Yielding Completed Survey	20,546
Non completed surveys	**9%**
Mid-survey termination	<1%
Household-level refusal	9%
Not Contacted – Respondent never available	**12%**
Unknown Eligibility	**76%**
Always busy	2%
No answer	14%
Answering machine-don't know if household	59%
Not Eligible	**2%**
Fax/data line	<1%
Disconnected number	<1%
Number changed	1%
Business, government office, other organizations	<1%
No eligible respondent	<1%

A.1.3 On-site Persistence

Two drivers underlie the on-site persistence research into short-term persistence and laying the groundwork for future EUL studies.[137] First, there are relatively few studies of persistence and EUL within the field of energy efficiency because program sponsors primarily allocate budget for process and impact evaluations that estimate annual savings rather than lifetime savings. Based on relatively simple primary research methods, the results of this study provide the EEB with Connecticut-specific information on persistence and EUL on the most common measures distributed through HES and HES-IE core services.

The second research driver is the commercial and industrial study conducted for NEEP (described earlier in this report) that included *some* multifamily units in its commercial-based sample and found that the 10-year persistence rate for compact fluorescent lamps (CFLs) was 33% and the two-year persistence rate was 73%. This raises the question of whether persistence may be similarly low for these programs.

The study presents two different variations on installation rates. The *verified installation rate* reflects the number of working lamps installed at the time of the site visit divided by the number of lamps in the tracking database. This value combines the effect of database and implementation issues with the effect of lamp removals, burnouts, and other lamp persistence factors. Note that the two-way mismatch between verified measures and tracking data greatly increases variance and thus reduces precision.

The *persistence rate* reflects the number of working lamps that were verified installed at the time of the site visit divided by the number of lamps that were verified received through the program. Thus, it excludes the effect of database and implementation issues reflected in the tracking data.

The verified installation rate calculation uses the following formula:

$$Verified\ Installation\ Rate = \frac{Verified\ Received\ Quantity\ - Removed\ Quantities}{Tracking\ Database\ Quantity}$$

Given the substantial differences in quantities found on site and verified to have been installed by the landlord or tenant compared to the tracking database, the analysis has not used these values in the calculation of persistence rates. Rather, this study uses the number of measures that were verified received as the basis for calculating persistence:

$$Persistence\ Rate = \frac{Verified\ Received\ Quantity\ - Removed\ Quantities}{Verified\ Received\ Quantity}$$

[137] It is important to distinguish between this study's assessment of short-term measure persistence and more rigorous assessments of measure lives relying on survival analysis to estimate *ex-post* measure-specific EULs. Guidelines for evaluating EULs are cited within the California Energy Efficiency Evaluation Protocols and Uniform Methods Project protocols.

A.2 Program Process

A.2.1 End-user Surveys – Program Process

The majority of HES and HES-IE end-user respondents first learned about utility rebates and incentives during the energy assessment. HES (13%) and HES-IE (11%) respondents often learned through word of mouth as well, and rebate-only participants often learned of it through contractors (35%) or CAAs or similar organizations (14%).

Table 81: Participant End-user Survey Respondents – Channels of Incentive Awareness

(Percentage of respondents)

First channel for learning about incentives	HES (n=433)	HES-IE (n=400)	Rebate-only (n=60)
During the Home Energy Assessment	28%	12%	11%
Word of mouth	14%	11%	4%
Utility company advertisement	7%	4%	7%
Community action agency or organization	6%	9%	14%
Utility company bill insert	6%	8%	4%
Utility company website	5%	5%	7%
Another organization	4%	15%	0%
Solar research / vendor / meeting	4%	0%	4%
Installation contractor or vendor	4%	2%	35%
Other	6%	7%	0%
Don’t know / Refused	16%	28%	15%

A.2.2 End-User Data Analysis – Wait Time

Table 82: HES End-user Records Marked for Exclusion from Wait-Time Analysis, by Vendor

Vendor Name	Total Records	Percent of Records Excluded
A Plus Installation, LLC	431	0.9%
Aiello Home Services	991	6.7%
BCB Conservation Group, LLC	445	3.6%
Climate Partners, LLC	157	1.9%
Competitive Resources, Inc.	1,279	5.0%
EcoSmart by R Pelton Builders, Inc.	1,959	2.8%
Energy Efficiencies Solutions, LLC	1,602	0.4%
Energy Resource Group	734	1.9%
EnergyPRZ, LLC	1,459	1.2%
Fox Heating Services, Inc.	323	0.3%
Greenbuilt Connecticut	269	28.6%
Gulick Building & Development, LLC	549	1.5%
Handyman Express Energy Solutions LLC	426	1.6%
Hoffman Fuel	198	2.5%
Home Doctor of America	408	4.9%
Lantern Energy, LLC	1,177	2.9%
Molina & Associates, Inc.	280	0.4%
New England Conservation Services, LLC	1,113	1.3%
New England Smart Energy Group, LLC	1,789	3.3%
Next Step Living, Inc.	3,834	7.5%
R&W Heating, LLC	263	3.8%
Santa Fuel, Inc.	434	4.4%
Tri City Home Energy Services	403	0.5%
Uplands Construction Group, LLC	409	1.2%
Victory Industries, LLC	1,467	2.5%
Wesson Energy, Inc.	1,390	2.4%
Other[1]	76	0.0%
Total	**23,865**	**3.8%**

[1] Vendors with fewer than 100 records have been combined into the "other" category.

A.3 Decision Making and Financing (R46)

A.3.1 End-user Participant Surveys – Decision Making and Financing

Table 83 is associated with Table 23 and includes all response options provided by HES respondents.

Table 83: HES End-user Participant Survey Respondents – Add-on Measure Decision-Making Factors

(Multiple responses, base = partial installers only)

Improvement Selection Reasoning	Measure Type			Total (n=204)
	Core Only (n=65)	Other add-ons (n=68)	Insulation (n=71)	
Least expensive	40%	31%	34%	37%
Biggest energy/utility bill savers	28%	32%	41%	32%
Easiest to install	25%*	16%	10%	20%
Already considering	3%	6%	1%	3%
Needed it	3%	3%	4%	3%
Age of equipment	2%	3%	1%	2%
Vendor recommendation	2%	4%	3%	2%
Easiest to find	2%	2%	4%	2%
Solar contractor recommendation	0%	0%	3%	1%
Other	3%	8%	10%	5%
Don't know/Refused	3%	1%	1%	2%

Note: Percentages are weighted. Respondents to this question are considered “partial installers” (those who have installed only some of the recommended measures).
* Indicates that core-only respondents were significantly more likely to make decisions based on what was easiest to install than insulation respondents at the 90% confidence level.

Table 84 is associated with Table 24 and includes all response options provided by HES respondents.

Table 84: HES End-user Participant Survey Respondents – Motivations to Make Additional Improvements

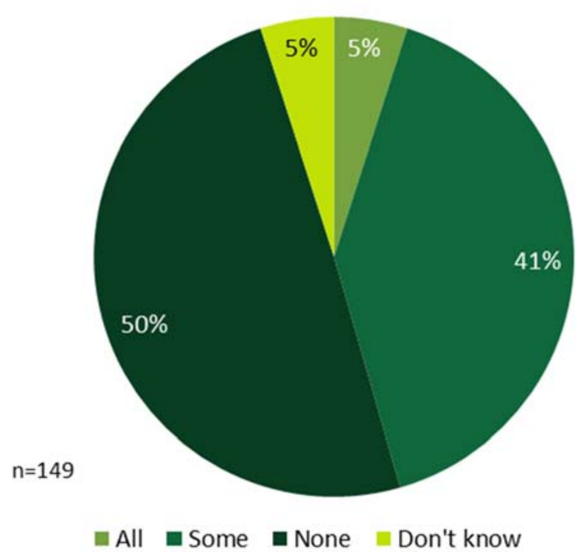
(Multiple responses, base = both partial installers and full installers)

Reasons for Making Improvements	Measure Type			Total (n=249)
	Core Only (n=81)	Other add-ons (n=74)	Insulation (n=94)	
Save money on energy bill	63%*	41%	49%	57%
Save energy	33%	33%	30%	32%
Comfort	6%*	16%**	1%	6%
Be "green" / help the environment	1%**	5%	11%***	4%
Increase ability to sell home or home value	2%	3%	1%	2%
Needed it	1%	1%	4%	2%
Health / safety	0%*	4%	7%	2%
Rebate	0%*	4%	4%	2%
Other	10%	12%	10%	10%

Note: Percentages are weighted.
* Indicates statistically significant difference from insulation and other add-on measure respondents at the 90% confidence level.
** Indicates statistically significant difference from insulation respondents at the 90% confidence level.
*** Indicates statistically significant higher than core service respondents at the 90% confidence level.

Figure 58: HES End-user Participant Survey Respondents – Likelihood to Install in the Next Year

(Base = non-installers only)



Note: Percentages are weighted.

Table 85 is associated with Table 26 and includes all response options provided by HES respondents.

Table 85: HES End-user Participant Survey Respondents – Reasons for Not Using Financing Options

(Multiple responses, base = partial or full installers not applying for financing)

Reasons for Not Using Financing	Measure Type			Total (n=158)
	Core Only (n=61)	Other add-ons (n=41)	Insulation (n=56)	
Have sufficient funds	41%	51%	50%	44%
Do not want debt	10%	13%	16%	12%
Did not have enough for down payment anyhow	8%	6%	5%	7%
Would not have been enough	5%	2%	4%	4%
Too much of a hassle	2%	2%	5%	3%
Application not approved	2%	0%	2%	2%
Used an outside loan option	2%	0%	0%	1%
Was not recommended	2%	0%	0%	1%
Other	7%	11%	7%	7%
Did not want to make the improvements anyway	18%	13%	7%	15%
Don't know/Refused	7%	2%	5%	6%

Note: Percentages are weighted.

Table 86 is associated with Table 27 and includes all response options provided by HES respondents.

Table 86: HES End-user Participant Survey Respondents – Reasons for Not Using Utility Rebates or Incentives

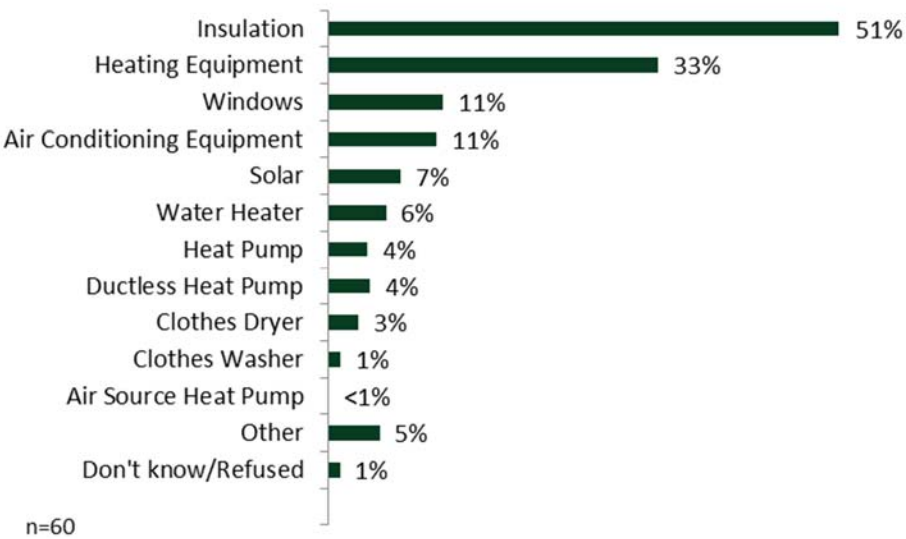
(Multiple responses, base = HES respondents not using rebates or incentives)

Reasons for not Using Rebates/Incentives	Survey Timing		Totals
	Short-term (n=25)	Long-term (n=315)	(n=340)
Have sufficient funds	26%	14%	15%
Did not have enough for down payment anyhow	15%	11%	11%
Unaware of rebates	12%	10%	10%
Expired/not enough time	14%	7%	7%
Would not have been enough	0%	7%	6%
Application not approved	0%	4%	4%
Too confusing	6%	3%	3%
Work not eligible	6%	3%	3%
Too much of a hassle	0%	3%	3%
Used Federal rebate	3%	0%	0%
Haven't made improvements yet	<1%	<1%	<1%
Up to landlord	<1%	<1%	<1%
Other	3%	7%	7%
Do want to make the improvements anyway	3%	21%	21%
Don't know/Refused	0%	3%	8%

Note: Percentages are weighted.

Figure 59: HES End-user Participant Survey Respondents – Improvements Made with Help of Program Financing

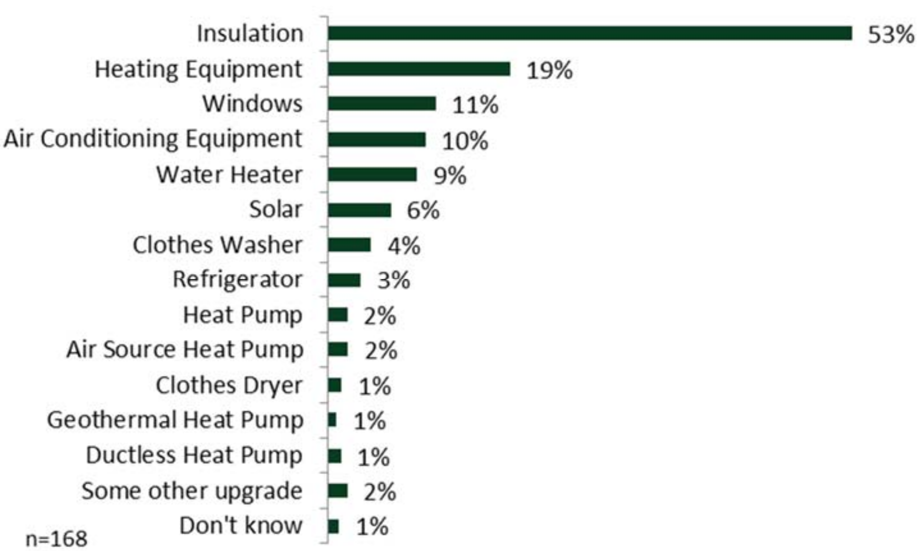
(Multiple responses, base = HES respondents at least somewhat aware of financing)



Note: Percentages are weighted.

Figure 60: HES End-user Participant Survey Respondents – Energy Improvements Made with Help of Rebates/Incentives

(Multiple responses, base = HES respondents at least somewhat aware of rebates and incentives)

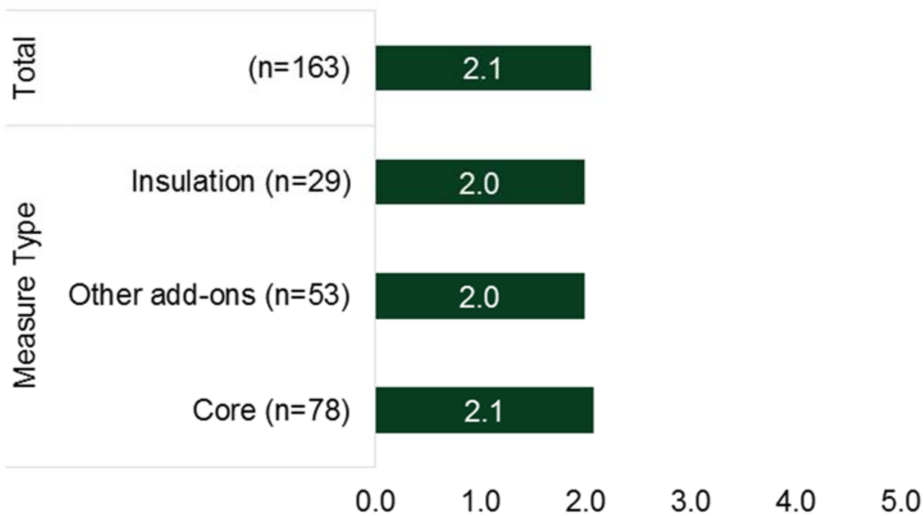


Note: Percentages are weighted.

As shown in Figure 61, HES respondents who did not recall having the vendor follow up with them after their initial visit and who did not install any additional improvements or only installed some of the recommended additional improvements speculated that they were only slightly likely to have moved forward with improvements if the vendor had followed up with them—both overall (mean rating of 2.1) and when compared by measure type.

Figure 61: HES End-user Participant Survey Respondents – Likelihood of Installing based on Vendor Follow-Up[1, 2]

(Mean rating, base = partial or non-installers who did not recall vendor follow up)



Note: Means are weighted.
[1] Responses were not broken out by survey time as all were attributed to the longer time period.
[2] Rated on a scale from 1 to 5, with 1 indicating "Not at all likely" and 5 indicating "Very likely."

A.3.2 End-user Nonparticipant Surveys – Decision Making and Financing

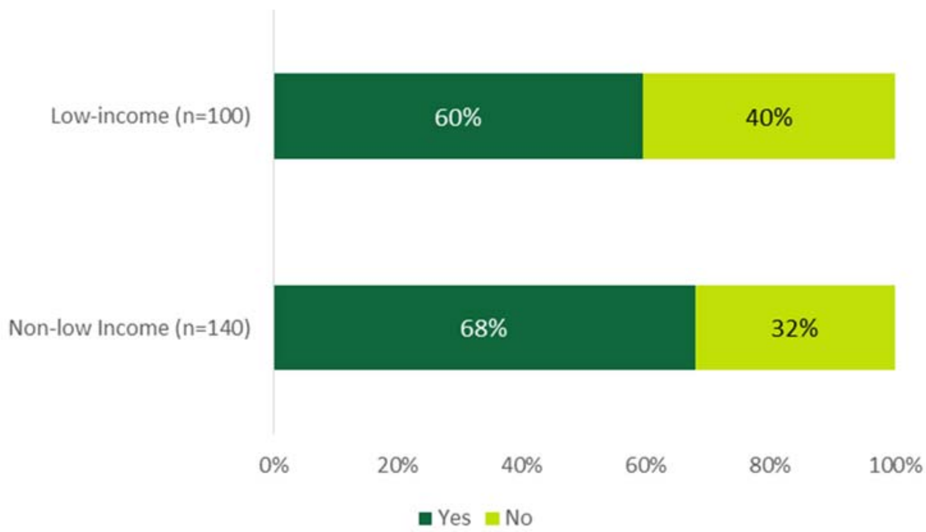
As shown in Figure 62, in the past year, over three-fifths of program nonparticipants (65%) have made improvements to their homes that were intended to increase energy efficiency. Note that these are self-reported purchases, and the study is not able to verify that the respondents actually obtained energy-efficient models. As shown in Table 87, light bulbs or lighting equipment improvements were the most common improvements made by both NLI nonparticipants (52%) and low-income nonparticipants (52%) that made improvements (installers). In reality, at least some of these bulbs were likely supported through upstream incentives at participating retailers, even if the purchasers did not realize they were taking part in a program.[138] Low-income nonparticipant installers also commonly installed refrigerators (23%), and NLI nonparticipants also commonly installed insulation (19%). NLI

[138] The exact number is unknown, but respondents to the R154 Lighting On-site Saturation Study indicated that they purchased 50% of CFLs and 70% of LEDs from home improvement and club stores, which carry the majority of upstream program bulbs in Connecticut.

nonparticipant installers (10%) were significantly more likely to have purchased an energy-efficient clothes washer than low-income nonparticipant installers (22%).

Figure 62: Nonparticipant Energy Efficiency Improvements in Last Year

(Base = all nonparticipants)



Note: Percentages are weighted.

Table 87 includes all response options provided by program nonparticipants.

Table 87: Nonparticipant Improvements Made

(Multiple responses, base = made improvements)

Improvements Made	Non-Low-Income (n=95)	Low-Income (n=59)
Light bulbs or lighting equipment	53%	52%
Refrigerators	17%	23%
Insulation	19%	16%
Clothes Washers	10%	22%*
Windows	16%	7%
Furnace	7%	7%
Central Air Conditioner	7%	3%
Appliances (General)	3%	7%
Doors	3%	4%
Stove	6%	1%
Heating System (General)	3%*	1%
Boiler	3%*	0%
Heat Pump	3%*	0%
Solar	3%*	0%
Dishwasher	3%	0%
Fuel Conversion	2%	0%
Windows	2%*	0%
Dryer	2%	0%
Showerheads	1%	1%
Other	4%	4%
Don’t know/Refused	2%	7%

* Indicates that low-income respondents were significantly more likely than NLI respondents to install clothes washers at the 90% confidence level.
Note: Percentages are weighted.

Table 88 is associated with Table 32 and includes all response options provided by program nonparticipants.

Table 88: Nonparticipant Reasons for Selecting Improvements Made

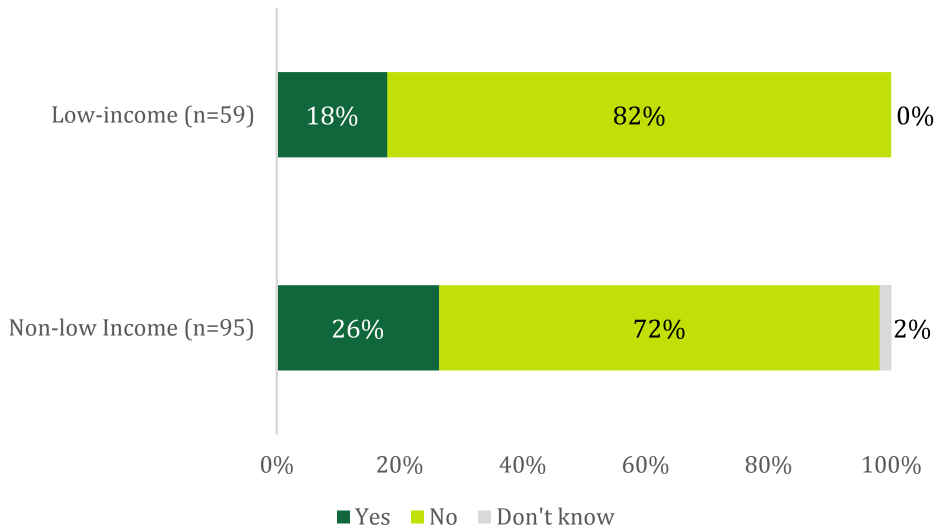
(Multiple responses, base = made improvements)

Reason for Choosing Improvements	Non-Low-Income (n=95)	Low-Income (n=59)
Greatest energy/utility savings	26%	21%
Replace aging/broken equipment	24%	18%
Most affordable	16%	21%
Easiest to find	8%	9%
Research/comparison shopping	8%	8%
Easy installation	7%	9%
Contractor/vendor recommendation	9%*	0%
Friend/family recommendation	3%	4%
Utility employee	1%	5%
Increased comfort	1%	5%
Most advanced technology	2%	0%
Most aesthetically pleasing	1%	1%
Store recommendation	1%	1%
Best quality	1%	0%
Other	6%	4%
Don't know/Refused	4%	12%

* Indicates statistically significant difference from low-income category at the 90% confidence level.
Note: Percentages are weighted.

Figure 63: End-user Nonparticipant Survey Respondents – Use of Utility Program Rebates

(Base = all nonparticipants)



Note: Percentages are weighted.

Table 89 is associated with Table 34 and includes all response options provided by program nonparticipants.

Table 89: Nonparticipant Reasons for Not Applying for Financing

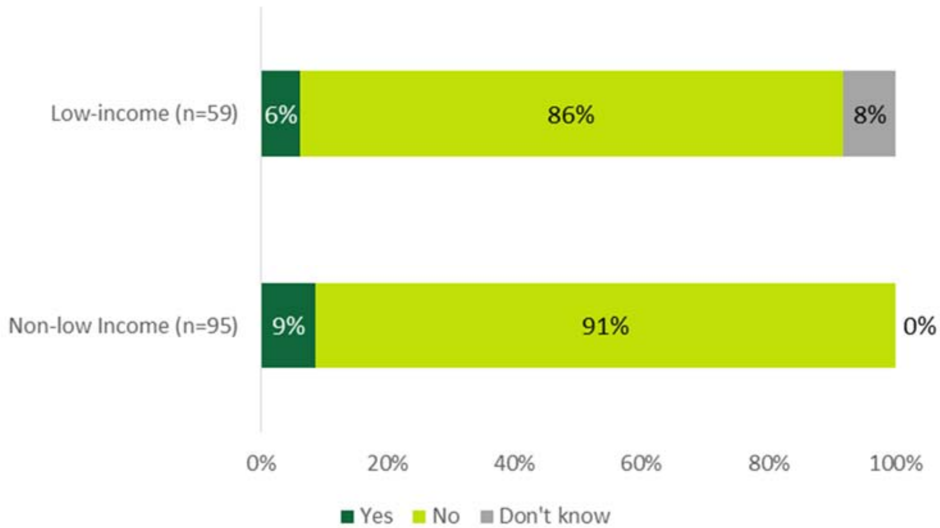
(Multiple responses, base = at least somewhat aware of financing)

Reason for Not Applying for Financing	Non-Low-Income (n=65)	Low Income (n=32)
Amount of money not sufficient	15%	23%
Not necessary	17%	8%
Did not want debt	13%	10%
Could not cover up-front cost	5%	14%
Did not want to make improvements	5%	10%
Just learning about program now	5%	6%
Have not had time	6%	5%
Did not qualify	5%	5%
Too much hassle	3%	5%
Used alternate financing	2%	5%
Already made upgrades	3%	0%
Did not receive assessment	2%	0%
Financing was not available	2%	0%
Have participated in the past	2%	0%
Too confusing	0%	0%
Other	10%	14%
Don't know/Refused	15%	14%

. *Note*: Percentages are weighted.

Figure 64: End-user Nonparticipant Survey Respondents – Financing Used

(Base = made improvements)



Note: Percentages are weighted. Sample includes nonparticipants who had made energy-saving improvements.

Table 90: End-user Nonparticipant Survey Respondents – Type of Financing Options Used

(Base = made improvements and used some type of financing options)

Financing Used	Non-Low-Income (n-8)	Low-Income (n=5)
Financing offered by my contractor	3	1
Zero percent payment plan	4	0
On-bill financing	0	3
Store financing	1	0
Residential Energy Efficiency Financing	0	1

Note: Unweighted counts given the small number of respondents.

A.3.3 HES Vendor Interviews – Decision Making and Financing

Table 91: HES Vendor Interviewees – Rebates Participants Like the Most and the Least

(Multiple responses, count of responses)

Rebates	Participants Like Most	Participants Like Least
	Yes[1]	No[2]
Insulation	21	-
Windows	4	1
Heating	2	1
Ductless Heat Pumps	2	1
HVAC (general)	1	2
Appliances	-	3
Solar	-	1
Depends	2	

[1] Includes "it depends" responses.
[2] Most focused on what people did get excited about, not what they did not, hence the small number of responses to this question.

A.4 Short-Term Persistence

Table 92: End-user Participant Survey Respondents – Reasons for Program Measure Removal

(Percentage of reasons given for removing measure)

	Light Bulbs		Water Saving Equipment		All Core Services[1]	
Issue	HES (n=66)	HES-IE (n=48)	HES (n=17)	HES-IE (n=22)	HES (n=134)	HES-IE (n=57)
Dissatisfied with product	42%	6%	41%	14%	39%	11%
Product broke	28%	46%	35%	41%	29%	42%
Product did not work properly	14%	21%	-	-	10%	13%
Product needed repairs	1%	6%	-	5%	3%	5%
Dissatisfied with installation	6%	6%	-	9%	4%	9%
Other	10%	15%	24%	32%	14%	20%
Don't know/Refused	-	-	-	-	1%	-

Note: Responses are weighted.
[1] Includes air sealing, light bulbs, duct sealing, water pipe wrap, and water-saving measures.

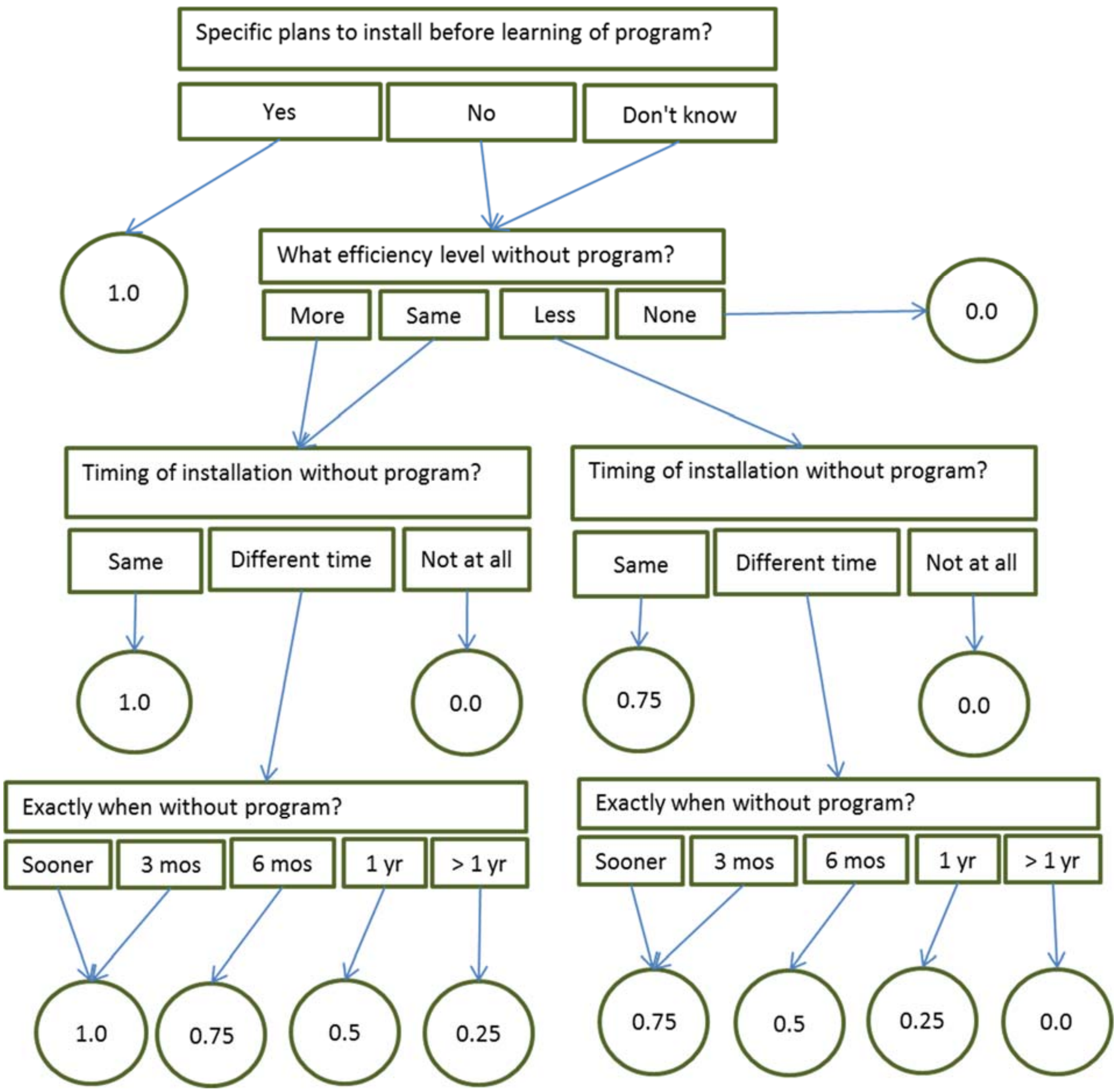
A.5 Net-to-Gross

The following appendix subsection includes additional details referred to in the body of the report.

A.5.1 Free Ridership

Figure 65 illustrates the logic sequence involved in estimating an initial end-user free ridership score. For add-on measures, the initial free ridership score is subsequently adjusted with the influence rating score by taking the product of the two scores.

Figure 65: End-user Participant Survey Respondents – Initial Free Ridership Scoring Method



The following are examples of how the analysis assigned free ridership scores to HES end-users' measures.

- **Example 1**: A respondent indicated that they had specific plans to install the same HVAC equipment as they had installed with a program incentive, receiving an initial free ridership score of 1.0. That respondent also gave a rating of 1 for all three elements, earning an influence-rating free ridership score of 1.0. The product of the two scores equals 1.0—a full-free-rider measure.
- **Example 2**: A respondent did not have specific plans to install the same light bulbs as were installed through the program (as a core service); however, that respondent speculated that they would have installed light bulbs of the same efficiency levels as they had received through the program, but would have installed them six months after they had been installed through the program. This is equated to an initial free ridership score of 0.75, and the surveys did not ask for influence ratings for core service measures. As a result, the final free ridership rate for the light bulbs is 0.75.
- **Example 3**: A respondent installed insulation through the program. They speculated that they would have installed the same amount outside the program, but would have installed it about a year after they had done it through the program. They received an initial free ridership rating of 0.5. When asked the influence-rating questions, the maximum rating they reported was 2, earning them an influence-rating score of 0.75. The product of these two scores is 0.38, the free ridership rate for this measure.
- **Example 4**: A respondent would have installed the same ductless heat pump as they had through the program and would have done so more than one year after participating, indicating an initial free ridership score of 0.25. That respondent also gave one of the three program elements a rating of 5, equaling an influence-rating free ridership score of 0.0. The final free ridership rate is therefore 0.0 (0.25 * 0.0).

The following are examples of how the analysis assigned free ridership scores to HES-IE landlords and property managers' measures.

- **Example 1:** One property manager said that they had specific plans to install insulation before installing it through the program. The interviewee clarified that they would have installed less insulation, however, and that, while they did not know exactly when, it would be "later." The study assumes that "later" would mean more than one year. The study considers this a non-free-rider measure, giving it a rate of 0.0.
- **Example 2:** Another property manager's company had already planned to install the same amount and type of water-saving measures that the program vendors installed; however, they had planned to do so more than one year later than the program had done it. Given that it was more than a year later, the analysis assigned that measure a partial free ridership rate of 0.25.
- **Example 3:** The third example was somewhat more complicated. The interviewee would have installed the same type of light bulbs at the same time in the absence of the program; considering these elements, the algorithm might initially result in a free ridership rate of 1.0. However, the interviewee clarified that they would have installed fewer light bulbs, which might indicate a free ridership rate of 0.75 if

installed at the same time, but since they would have been the same type of light bulb, the analysis used the average rate between 0.75 and 1.0: 0.88.

- **Example 4:** In another case, an interviewee planned to install more of the water-saving measures of the same type and would have done so within three months of the program vendor doing so. Because they would have installed more and the timing was so close, the analysis assigned a full free ridership rate of 1.0.

Table 93 presents the free ridership rates for rebate-only end-users.

Table 93: Rebate-only End-user Participant Survey Respondents – Free Ridership Rates

Measure (n=58 respondents)	N	Average Free Ridership Rate	Sum of Gross Savings (MMBtu/yr)[1]	Confidence Interval[2]	
				Maximum	Minimum
AC equipment	14	0.18	22.6	0.35	0.01
Air source HP	5	0.10	38.4	0.32	0.00
Ductless HP	34	0.15	181.6	0.26	0.05
Geothermal HP	2	0.12	10.4	0.50	0.00
Heating equipment	8	0.00	121.6	0.00	0.00
Total	**63**		**374.7**		
Weighted average free ridership[3]		**0.07**		**0.13**	**0.02**

[1] Savings in the program database are associated with the respective measure and respective interviewees. Electric, gas, oil, and propane savings have been converted into MMBtu/year.
[2] Figures are at a 90% confidence level.
[3] The free ridership rate is weighted by gross annual savings.

A.5.2 Spillover

The table below presents the spillover-eligible measures that landlords and property managers installed and the resulting spillover rate.

Table 94: HES-IE Landlord and Property Manager Interviewees – Spillover Rate

Measure	Count of interviewees	% of interviewees (n=29)
Door sweeps	1	3%
Storm doors	1	3%
Lighting motion sensors	1	3%
Spillover		**0.03**

A.6 Non-Energy Impacts

Non-energy impacts, or NEIs, refer to benefits or drawbacks that participants experience as a result of program participation that do not tie directly to energy use or savings. They can considerably affect a participant's decision to adopt a measure and their experience with the measure post-installation.[139]

A.6.1 Non-Energy Impacts Calculation Methodology

For any elements where participants observed positive or negative impacts as a result of the program, questions asked them to compare the value of that NEI to the impact of the program on energy savings. After asking about individual NEIs, the questions asked them to consider the net impacts of NEIs combined—qualitatively and quantitatively. From these inputs, the study estimated NEI values. Table 95 presents the inputs into the NEI algorithm and the survey and interview questions associated with them. The analysis involved five primary steps:

- **Develop magnitude scale**. The analysis began with calculating the average *numeric values of combined effects* (row *f* in Table 95) that respondents gave that were associated with the *qualitative value of combined effects* (*e*) that they gave. This resulted in what can be referred to as a *magnitude scale* where *much more negative value* is associated with the lowest percentage (a value below zero) and *much more positive value* is associated with the highest percentage (a value above zero). *No effect* is always associated with a value of zero.
- **Apply magnitude values**. The study then applied the magnitude scale values to the given qualitative values for each of the individual NEIs (*b*) so that each respondent had a value associated with each of their responses for each NEI element. For example, if the magnitude scale determined that *somewhat more negative value* was equivalent to -130%, and a respondent estimated that comfort was negatively impacted and that the negative impact was *somewhat more negative* than the value of the expected energy savings, then the value of -130% would be applied to that respondent for that NEI.
- **Correct for overlaps.** In any cases where end-users articulated which, if any, of the individual NEIs overlapped, the analysis divided their individual NEI magnitude scores for any NEIs that they identified as overlapping. This step accounts for any over-counting of one individual NEI.
- **Normalize values.** After applying magnitude values, the study compared each respondent's given numeric value of combined effects (*f*) with the sum of the values of the individual NEIs that they had reported. The study then proportionally decreased the individual NEI values so that they did not total to greater than the value of that respondent's reported combined effects.
- **Estimate final NEI values.** The overall NEI value is equal to the average value of the combined effects across respondents (*f*). In the same vein, the value of the individual NEIs are the average normalized values associated with those NEIs across respondents.

[139] Skumatz, Lisa A., "Estimating Participant Non-Energy Benefits for Households and Businesses," August 2015.

- **Impute missing values.** Due to a CATI survey programming misunderstanding, 71% of respondents who should have been asked to provide qualitative (*e*) or quantitative (*f*) estimates of the combined net effects were not asked. The team sought to call back a statistically adequate number of these contacts, setting goals of 68 HES/rebate-only and 68 HES-IE respondents (20% of those that were erroneously skipped). Using the responses of the called-back respondents and those that originally went through the module correctly, the analysis imputed an overall NEI value of those that were mistakenly skipped by first taking the sum of their non-normalized magnitude values as a proxy for the combined effects, and second using the average sum of their non-normalized values and reducing it using the ratio of the average combined effects to the average sum of the non-normalized magnitude values among respondents that actually went through the module correctly. Their average non-normalized magnitude values for the individual NEIs were then normalized overall (instead of at a respondent level); those values were then weighted with the average overall individual normalized NEI values of those that went through the module correctly to estimate final values for the individual NEIs.

Table 95: Non-Energy Impacts Inputs and Related Research Instrument Questions

Input	Related Survey / In-depth Interview Question
Impact on individual elements (a)	Did the program have a positive effect, negative effect, or no effect on [list of NEIs]
Qualitative value of impact on individual elements (b)	How does the value of the positive/negative effect on [NEI] compare to the value of the expected energy savings?
	Does the **positive** effect have much less value, somewhat less value, same value, somewhat more value, or much more value?
	Does the **negative** effect have much more negative value, somewhat more negative value, same value or balances out, somewhat less negative value, or much less negative value?
Overlap of impact on individual elements[1] (c)	Thinking about all these effects that you have mentioned are there any that you think “overlap” or that you had a hard time separating out?
Net combined effects (d)	Now, think about the combination of all the positive and negative effects that you received from the program not including possible energy savings. Would you say that the combination of these effects is overall positive, negative, or had no effect?
Qualitative value of combined effects (e)	How does the overall positive/negative value of the combination of these effects compare to the value of the expected energy savings?
	Does the **positive** combination of effects have much less value, somewhat less value, same value, somewhat more value, or much more value?
	Does the **negative** combination of effects have much more negative value, somewhat more negative value, same value or balances out, somewhat less negative value, or much less negative value?
Numeric value of combined effects (f)	If you were to estimate its value as a fraction, percentage, or multiple, by about what amount more or less valuable is the combination of **positive** effects? We’d like to know a value relative to average energy bill savings.
	If you were to estimate its cost as a fraction, percentage, or multiple, by about what amount more or less **negative** is the value of the combination of effects? We’d like to know a value relative to average energy bill savings.

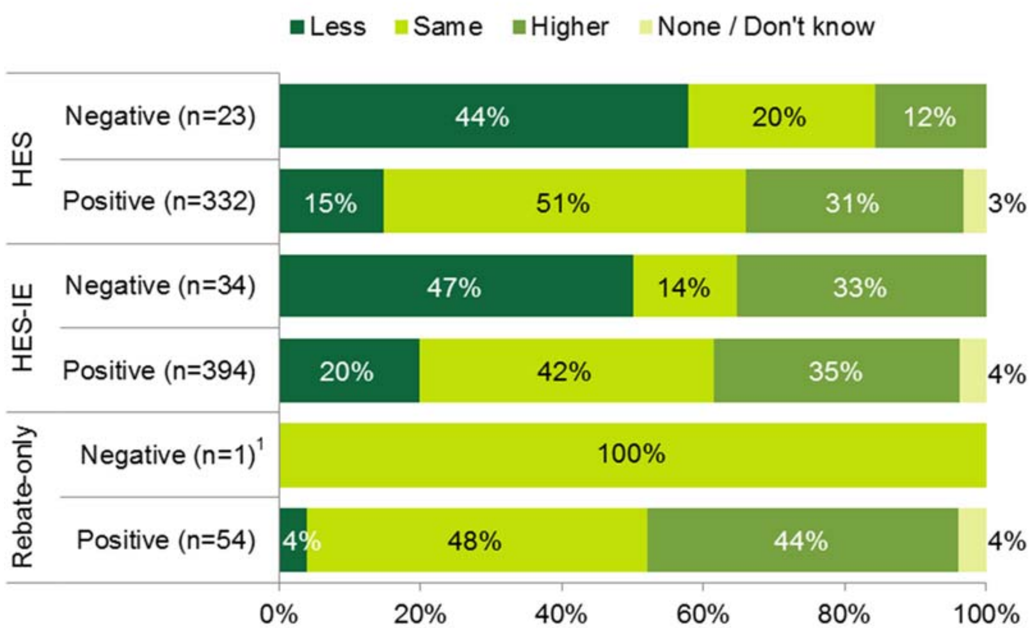
[1] Nonparticipant end-user surveys and HES-IE landlords and property manager interviews did not ask about overlaps.

A.6.2 End-user Participant Surveys – Non-energy Impacts

HES (51%) and HES-IE (42%) end-user respondents were most likely to think that the net positive impact that they experienced from the NEIs was about equal to what they expected, but responses were mixed, with about one-third of each group (31% HES and 35% HES-IE) finding that the positive net impact was higher than what they expected. The negative responses were few, but HES (44%) and HES-IE (47%) respondents were most likely to have expected less of a negative net impact than they did. Figure 66 illustrates these differences in detail.

Figure 66: End-user Participant Survey Respondents – Comparison between Net Non-Energy Impacts and Expected

(Percentage of NEI respondents)



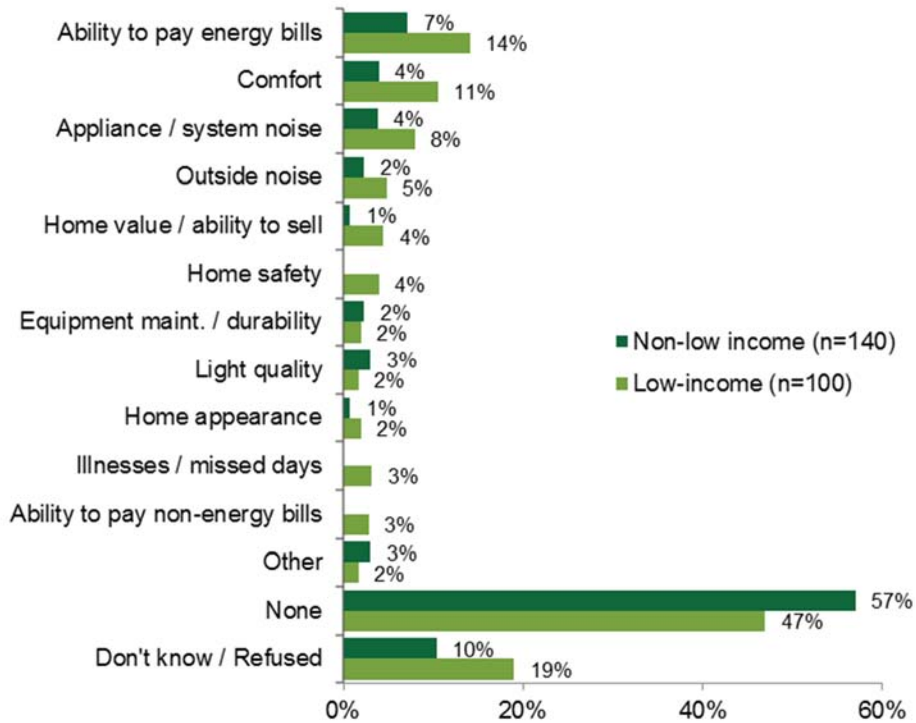
Note: Percentages are weighted. Respondents answered the following question: *Is the overall positive or negative value of the combination of these energy and non-energy effects less than, equal to, or higher than what you expected at the time of participation in the program?*

[1] Due to weighting, this single respondent's response actually has no value, and is included here only for illustrative purposes.

A.6.3 Nonparticipant End-user Surveys – Non-energy Impacts

Figure 67: Nonparticipant Survey Respondents – Speculations of Possible Non-Energy Impacts

(Multiple responses (unprompted), percentage of respondents)

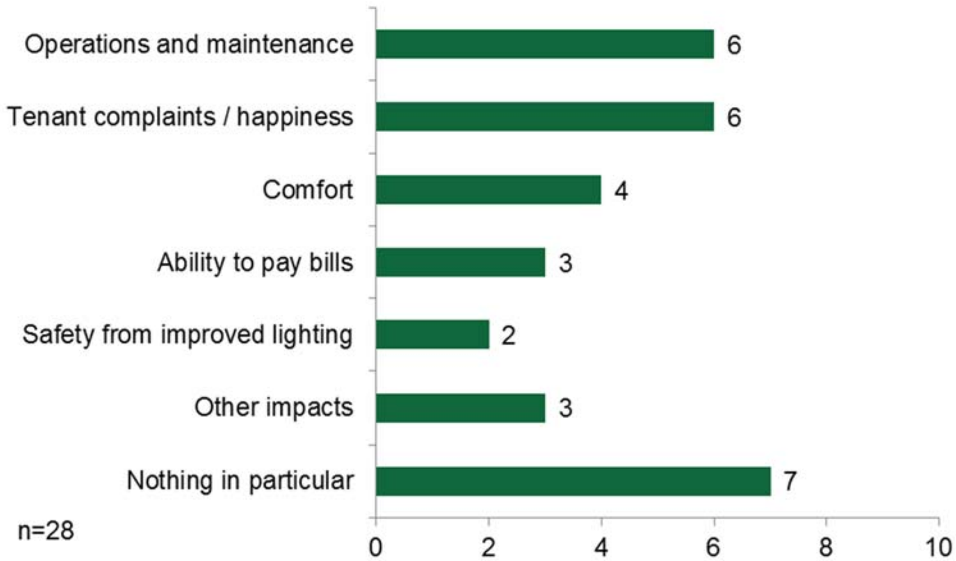


Note: Responses are weighted.

A.6.4 HES-IE Landlords and Property Manager Interviews – Non-Energy Impacts

Figure 68: HES-IE Landlord and Property Manager Interviewees – Non-Energy Impacts Expected Prior to Participating

(Multiple responses, count of respondents)



Five of the landlords and property managers recalled their vendors discussing NEIs and emphasizing that the landlord or property manager would need to change the light bulbs less frequently (three), tenants' comfort would be increased (two), and tenants' ability to pay their rent would improve (one).

A.7 Health and Safety

Table 96: End-user Participant Survey Respondents – Reasons for Not Remedying Health and Safety Issues

Explanation	Count of Respondents (Multiple Responses)	
	HES (n=12)	HES-IE (n=42)
Too expensive	3	15
Have not gotten around to it	2	5
Unable to find contractor	-	1
Repair/removal scheduled	-	5
Too much trouble	1	1
Repair/removal not possible	2	-
Repair/removal deemed unnecessary	1	2
Incorrect assessment of issue	2	7
Requires action by landlord	1	4
Awaiting additional information	1	0
Don't know	-	15

Note: Responses are unweighted

Table 97: End-user Nonparticipant Survey Respondents – Reasons for Not Remedying Health and Safety Issues

Explanation	Count of Respondents (Multiple Responses)		
	Non-Low-Income (n=6)	Low-Income (n=6)	Total (n=12)
Too expensive	2	4	6
Have not gotten around to it	4	-	4
Repair/removal scheduled	-	1	1
Repair/removal deemed unnecessary	1	1	2
Requires action by landlord	-	2	2
Don't know	1	1	2

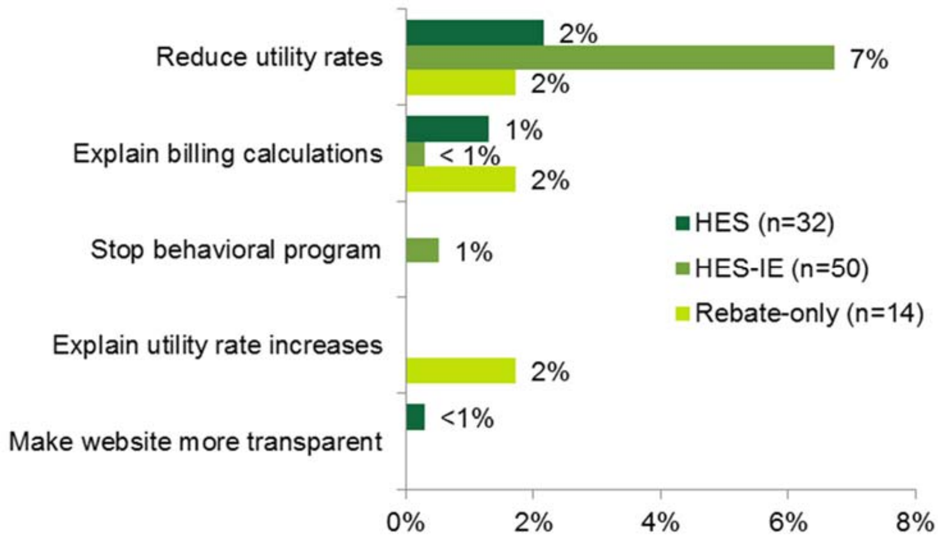
Note: Responses are unweighted

A.8 Additional Feedback

Short-term survey respondents had very few suggestions for ways that the Companies could improve their services. Most often they had concerns about energy rates (Figure 69).

Figure 69: End-User Participant Surveys – Suggestions for the Companies' Services

(Percentage of respondents)



Note: Sample sizes are small because this question was asked only of short-term respondents.

B

Appendix B Additional Characteristics

This section contains additional details about respondents and interviewees.

B.1 End-user Respondents – Housing Characteristics and Demographics

B.1.1 End-user Participant Surveys – Housing Characteristics and Demographics

Table 98: End-user Participant Survey Respondents – Age of Respondent

Age Group	HES (n=547)	HES-IE (n=525)	Rebate-only (n=60)
18-24 years	2%	1%	-
25-44 years	25%	26%	21%
45-64 years	46%	39%	57%
65 years or older	24%	33%	22%
Don't know/Refused	3%	1%	-

Note: Responses are weighted

Table 99: End-user Participant Survey Respondents – Ownership Status of Respondent

Ownership Status	HES (n=547)	HES-IE (n=525)	Rebate-only (n=60)
Own	95%	72%	100%
Rent	2%	26%	0%
Don't know/Refused	3%	2%	0%

Note: Responses are weighted

Table 100: End-user Participant Survey Respondents – Type of Home

Type of Home	HES (n=547)	HES-IE (n=525)	Rebate-only (n=60)
Single Family	90%	64%	93%
Two to four units	3%	18%	3%
Multifamily	2%	9%	-
Townhouse	2%	5%	4%
Mobile home	1%	3%	-
Don't know/Refused	2%	1%	-

Note: Responses are weighted

Table 101: End-user Participant Survey Respondents – Length of Residency in Current Home

Years in Home	HES (n=433)	HES-IE (n=400)
Less than 1 year	1%	1%
1-2 years	15%	10%
3-5 years	14%	20%
6-7 years	5%	6%
8-10 years	11%	11%
11-15 years	15%	15%
16-20 years	7%	10%
More than 20 years	31%	26%
Don't know/Refused	1%	1%

Note: Responses are weighted

Table 102: End-user Participant Survey Respondents – Highest Level of Education Achieved

Level of Education	HES (n=547)	HES-IE (n=525)	Rebate-only (n=60)
Less than High School	1%	6%	-
High School or equivalent	7%	27%	7%
Some college	9%	22%	11%
Associate's Degree	9%	17%	14%
Bachelor's Degree	31%	17%	28%
Graduate or Professional Degree	39%	8%	36%
Don't know/Refused	4%	3%	4%

Note: Responses are weighted

Table 103: End-user Participant Survey Respondents – Mean Occupancy of Home

	HES (n=547)	HES-IE (n=525)	Rebate-only (n=60)
Mean number of occupants	2.8	2.6	2.9

Note: Responses are weighted

Table 104: End-user Participant Survey Respondents – Household Income

Income Group	HES (n=547)	HES-IE (n=525)	Rebate-only (n=60)
Less than $10,000	1%	9%	-
$10,000-$14,999	1%	13%	-
$15,000-$24,999	2%	25%	-
$25,000-$34,999	2%	15%	4%
$35,000-$49,999	5%	13%	-
$50,000-$74,000	12%	7%	18%
$75,000-$99,999	13%	3%	7%
$100,000-$149,999	20%	1%	30%
$150,000-$199,999	8%	1%	7%
$200,000 or more	16%	1%	7%
Don't know/Refused	20%	12%	27%

Note: Responses are weighted

Table 105: End-user Participant Survey Respondents – Low-income vs. NLI (based on HUD Median Income Limits)

Income Type	HES (n=547)	HES-IE (n=525)	Rebate-only (n=60)
Low-income	8%	69%	10%
Non low-income	70%	19%	66%
Don't know/Refused	21%	12%	24%

Note: Responses are weighted

B.1.2 End-user Nonparticipant Surveys – Housing Characteristics and Demographics

Table 106: End-user Nonparticipant Survey Respondents – Age of Respondent

Age Group	Non-Low-Income (n=140)	Low-Income (n=100)
18 to 24 years old	3%	2%
25 to 44 years old	30%	29%
45 to 64 years old	47%	40%
65 years or older	19%	26%
Don't know / Refused	1%	2%

Note: Responses are weighted.

Table 107: End-user Nonparticipant Survey Respondents – Ownership Status of Respondent

Ownership Status	Non-Low-Income (n=140)	Low-Income (n=100)
Own	93%	73%
Rent	6%	22%
Don't know/Refused	1%	5%

Note: Responses are weighted.

Table 108: End-user Nonparticipant Survey Respondents – Type of Home

Type of Home	Non-Low-Income (n=140)	Low-Income (n=100)
Single family	81%	48%
Two or three family	5%	12%
Multifamily with three or more units	2%	29%
Townhouse	12%	7%
Mobile home	-	1%
Don't know/Refused	-	2%

Note: Responses are weighted

Table 109: End-user Nonparticipant Survey Respondents – Length of Residency in Current Home

Years in Home	Non-Low-Income (n=140)	Low-Income (n=100)
Less than one year	4%	7%
One or two years	8%	12%
Three to five years	15%	14%
Six to seven years	10%	8%
Eight to ten years	12%	6%
Eleven to fifteen years	17%	12%
Sixteen to twenty years	8%	20%
More than twenty years	25%	18%
Don't know/Refused	1%	2%

Note: Responses are weighted.

Table 110: End-user Nonparticipant Survey Respondents – Highest Level of Education Achieved

Education Level	Non-Low-Income (n=140)	Low-Income (n=100)
Less than high school diploma	-	1%
High school diploma or GED	8%	19%
Some college	17%	24%
Associates or technical school degree	8%	15%
Bachelor's degree	30%	20%
Graduate or professional degree	33%	12%
Don't know/Refused	4%	8%

Note: Responses are weighted.

Table 111: End-user Nonparticipant Survey Respondents – Mean Occupancy of Home

	Non-Low-Income (n=140)	Low-Income (n=100)
Mean number of occupants	2.8	2.6

Note: Responses are weighted

Table 112: End-user Nonparticipant Survey Respondents – Household Income

Income Group	Non-Low-Income (n=140)	Low-Income (n=100)
Less and $10,000	-	6%
$10,000 to $14,999	-	6%
$15,000 to $24,999	-	21%
$25,000 to $34,999	1%	17%
$35,000 to $49,999	2%	26%
$50,000 to $74,999	27%	24%
$75,000 to $99,999	29%	-
$100,000 to $149,999	11%	-
$150,000 to $199,999	9%	-
$200,000 or more	7%	-
Don't know/Refused	14%	-

Note: Responses are weighted

Table 113: End-user Nonparticipant Survey Respondents – Low-income vs. NLI (based on HUD Median Income Limits)

Income Type	Non-Low-Income (n=140)	Low-Income (n=100)
Low-income	140	100
Non low-income	100	140

Note: Responses are weighted

B.2 HES-IE Landlord and Property Manager Interviews – Additional Characteristics

B.2.1 HES-IE Landlord and Property Manager Interviews – Key Project Attributes

For the most part, the HES-IE landlord and property managers' key participating projects were of average size in terms of number of tenant units. The number of participating units within interviewees' sampled projects ranged from five to 360 units, with an average of 79 units per project.[140] Most often they had fewer than 50 units, with only a few projects that were very large and included 200 units or more (Table 114).

Table 114: HES-IE Landlord and Property Manager Interviewees – Number of Units at Key Project

Number of Participating Units	Count of Key Projects (n=30)
300-360	2
200-299	1
100 to 199	4
50 to 99	6
25-49	9
<25	8
Total	**2,360**
Average	**79**
Median	**41**

140 For example, average project size among Eversource's HES-IE SP3 population database included 78 units (n=263 projects). UI's database did not identify the number of units associated with the projects.

B.2.2 HES-IE Landlord and Property Manager Interviews – Company Firmographics

Most HES-IE landlord and property manager interviewees' companies are relatively small, yet they range in size from one employee to 2,000 employees, averaging 141 employees. Over one-half of the interviewees (18) own or work for companies that employ fewer than 25 employees.

Table 115: HES-IE Landlord and Property Manager Interviewees – Total Employees at Company

Total Employees	Count of Interviewees (n=30)
2,000 or more	1
100 to 1,999	2
50 to 99	4
25 to 49	4
10 to 24	5
5 to 9	2
Fewer than 5	11
Don't know	1
Total	**4,081**
Average	**141**

In total, landlord and property manager interviewees manage 378 buildings (Table 116) with 20,037 units (Table 117) in Connecticut, averaging 13 buildings and 716 units.[141] They were most likely to have small to medium enterprises: most commonly managing ten or fewer buildings (19) and fewer than 500 units in Connecticut (17).

[141] One interviewee could not estimate the number of buildings that the company managed, and two could not estimate the number of units. The results include the number of buildings and units that are associated with their key project in this total figure, but exclude it from averages and include it as a "Don't know" response in the tables.

Table 116: HES-IE Landlord and Property Manager Interviewees – Total Buildings Managed/Owned in Connecticut

Number of Buildings with Five or More Units in Connecticut	Count of Interviewees (n=30)
41 to 50	3
31 to 40	1
21 to 30	1
11 to 20	5
5 to 10	8
Fewer than 5	11
Don't know	1
Total	**378**
Average	**13**

Table 117: HES-IE Landlord and Property Manager Interviewees – Total Units Managed/Owned in Connecticut

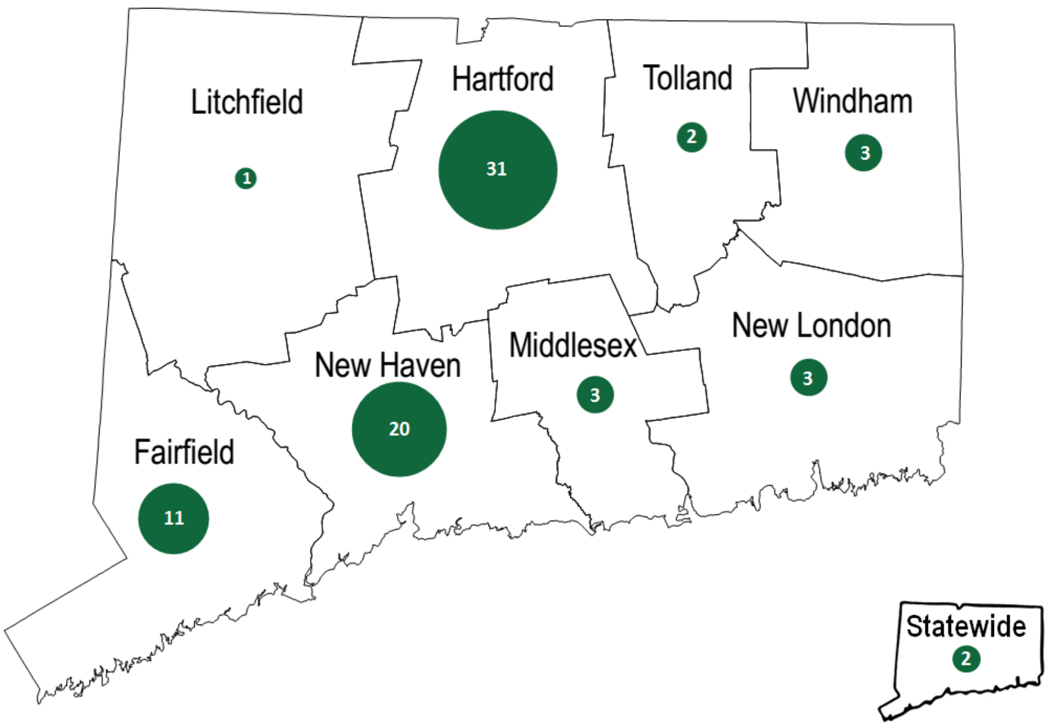
Total Units Managed/Owned in Connecticut	Count of Interviewees (n=30)
3,000 or more	1
2,000 to 2,999	2
1,500 to 1,999	2
1,000 to 1,449	4
500 to 999	2
250 to 499	5
100 to 249	5
Fewer than 100	7
Don't know	2
Total	**20,037**
Average	**716**

Landlord and property manager interviewees most commonly managed properties within Hartford (31), New Haven (20), and Fairfield (11) Counties (Figure 70):

- Two of the 30 interviewees said that they owned or managed properties all across Connecticut.
- The cities and towns in Hartford County that they listed most frequently included Hartford (10), Newington (5), and New Britain (4).

- Aside from listing New Haven County (2) *generally*, they frequently specifically identified the cities of Waterbury (6) and New Haven (5).

Figure 70: HES-IE Landlord and Property Manager Interviewees – Geographical Distribution of Properties



Note: The size of the circle within each county corresponds with the number of times interviewees identified either 1) the county itself or 2) a town/city within the county as a place where their properties were located.

B.2.3 HES-IE Landlord and Property Manager Interviews – Short-Term Persistence

Only two interviewees indicated that measures installed through the program had been removed. At one property, two low-flow showerheads had been removed by tenants who did not like them; the interviewee speculated that the maintenance person had stored the units and estimated that they were removed fairly soon after they were installed. At another property, a couple of CFLs installed through the program burnt out at some point after being installed and were subsequently replaced with new CFLs that were identical to those installed through the program but were not issued through the program.

Table 118: HES-IE Landlord and Property Manager Interviewees – Reported Measure Removal at Key Project

Removed Program Measures	Count of Interviewees (n=30)
No	26
Yes	2
Don't know	2
Type of Measure Removed	**Quantity Removed**
Low-flow showerheads	2
CFLs	2
Total	**4**

B.2.4 HES-IE Landlord and Property Manager Interviews – Health and Safety

Five of the 30 landlord and property manager interviewees said that vendors had identified health or safety problems during the energy assessment. Vendors discovered mold at all five of these properties and a gas leak at one of the five. The health and safety problems delayed the initial assessment at only one of the five properties until maintenance staff had remediated the problem. The interviewees confirmed that all of these health and safety problems had been resolved since the initial visit.

Table 119: HES-IE Landlord and Property Manager Interviewees – Reported Health and Safety Problems at Key Project

(Multiple responses)

Health and Safety Problems	Count of Interviewees (n=30)
No issues found	24
Mold	5
Gas Leak	1
Don't know	1

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Prepared for: Massachusetts Program Administrators

Tetra Tech
6410 Enterprise Lane, Suite 300 | Madison, WI 53719
Tel 608.316.3700 | Fax 608.661.5181
www.tetratech.com

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NEI Reporting Category	n	Kerosene			Water Usage		
		Average NEI (gallons)	Gallons/ Therm	Stat Sig	Average NEI (Gallons)	Gallons/ Therm	Stat Sig
Building Envelope	46	0	0.0000	No	0	0.0000	No
HVAC	41	643	0.0526	No	0	0.0000	No
Water Heater	23	0	0.0000	No	287,594	65.3489	No
Other	2	0	0.0000	No	0	0.0000	No
Overall	**112**	**338**	**0.0431**	**No**	**48,670**	**6.2021**	**No**

1. EXECUTIVE SUMMARY

This report presents the Massachusetts Cross-Cutting Evaluation Team's analysis of Non-Energy Impacts (NEI) attributable to 2010 commercial and industrial (C&I) retrofit programs administered by the Massachusetts Program Administrators (PA). Non-Energy Impacts include positive or negative effects attributable to energy efficiency programs apart from energy savings.

DNV KEMA embarked on this study to fulfill the directive set forth by the State's Department of Public Utilities to update and improve non-energy impact estimates for use in the PA's 2013 to 2015 energy efficiency three-year plan and future annual plans. In addition, the PAs will use this study to assist in program marketing, as NEIs increase the value proposition of Energy Efficiency programs for participants.

The goal of this study was to provide a comprehensive set of statistically reliable NEI estimates across the range of C&I retrofit programs offered by the Massachusetts electric and gas PAs.

DNV KEMA identified the following objectives for this study:

1. Quantify participant NEIs by gross NEIs per unit of energy savings separately for prescriptive and custom electric and gas measures;
2. Examine the attribution rates of individuals who did and did not realize NEIs to inform the appropriate free-ridership rate for computing net NEIs; and
3. Identify incidence of spillover, or energy savings resulting from program-influenced installation of energy efficiency measures that did not receive program incentives, by providing separate estimates for the incidence of "like"[1] and "unlike"[2] spillover.

1.1 OVERVIEW OF APPROACH

Drawing on the lessons learned from both the TecMarket Works and Optimal Energy research [3] [4], the evaluation team conducted a large scale in-depth interview (IDI) effort with sufficient sample to provide statistically significant NEI estimates across prescriptive and custom electric and gas measure groups.

The development of the study proceeded in the following steps:

---

[1] We define "like" spillover as energy savings resulting from program influenced installation of energy-efficient equipment of the same type (i.e. the same measure, capacity, and efficiency level).

[2] We define "unlike" spillover as energy savings resulting from program influenced installation of energy-efficient equipment of a different type (i.e. different measure, capacity, or efficiency level)

[3] TecMarket Works. "*Non-Electric Benefits from the Custom Projects Program: A look at the effects of custom projects in Massachusetts*" Prepared for: National Grid. Roth, Johna and Nick Hall. September 25, 2007.

[4] Optimal Energy, Inc. *Non-Electric Benefits Analysis Update. D.P.U. 09-119.* Attachment AG-1-22 (j). *. Mosenthal, Phil and Matt Socks. November 7, 2008.*

1. Selected sample for telephone interviews with 2010 Massachusetts C&I custom and prescriptive energy efficiency program participants.
   - For prescriptive measures, the evaluation team selected the sample from the 1,499 measures completed by the 2011 free-ridership and spillover (FR/SO) survey with 2010 program participants;
   - For custom measures, the evaluation team conducted surveys with the 258 respondents to the 2010 participant FR/SO survey with 2010 program participants, and supplemented this sample with 2010 custom program participants who did not complete the FR/SO surveys;
2. Designed the survey instruments and trained the interview staff;
3. Conducted the semi-structured interviews using experienced DNV KEMA energy analysts and oversaw quality control;
4. Collected data on NEI types and dollar values, and like and unlike spillover. Separate NEI data obtained for the following mutually exclusive categories:
   - Operations and maintenance costs;
   - Administrative or other labor not associated with operations or maintenance;
   - The cost of supplies, materials and materials handling;
   - Transportation or materials movement costs;
   - Other labor costs;
   - Water usage;
   - The amount of product spoilage or defects;
   - Waste disposal costs
   - Fees including insurance, inspections, permits and legal fees;
   - Other costs;
   - Sales;
   - Rent revenues;
   - Other revenues.
5. Calculated NEIs by predetermined measure categories;
6. Estimated like and unlike spillover; and
7. Combined NEI survey results with 2010 participant FR/SO survey results to examine the relationship between NEIs and program attribution.

1.2 KEY FINDINGS

Table 1-1 presents a summary of the number of measures reporting NEIs of different magnitudes across all measures and fuel types. The evaluation team captured NEI information for 789 prescriptive and custom electric and gas measures. Positive NEIs or non-energy benefits were realized for 58% of measures, while 3% of measures resulted in negative NEIs. An additional 40% of measures reported no positive or negative NEIs.

Table 1-1 Number of measures reporting NEIs by Size of NEI

NEI Value	Number of measures	Percent of measures
Negative	22	3%
Zero	315	40%
Greater than Zero to $1,000	235	30%
Greater than $1,000 to $5,000	119	15%
Greater than $5,000 to $10,000	44	6%
Greater than $10,000 to $15,000	15	2%
Greater than $15,000 to $50,000	29	4%
Greater than $50,000 to $100,000	8	1%
Greater than $100,000	2	0%
Total	789	

1.2.1 Gross Non-Energy Impacts

Our analysis identified the presence of NEIs resulting from energy efficiency programs, providing statistically significant NEI estimates and also identified that there was a significant correlation between program savings and the level of NEIs reported. The evaluation team found a strong and statistically significant correlation between NEIs and savings for the following measures: prescriptive electric, custom electric and custom gas. We also found a statistically significant correlation between NEIs and savings for prescriptive gas, but this result was not as strong, largely resulting from the low sample size.

Table 1-2 summarizes the results of our analysis.[5]

[5] For the prescriptive electric study the “other” reporting category included the comprehensive and compressed air end uses. For the custom electric study the “other” reporting category included the building envelope, compressed air, process and other end uses. The “other” reporting category for custom gas included the process and other end uses

Table 1-2 Summary of Average Annual NEI Estimates

Electric measures	n	Average Annual NEI per Measure*	NEI/kWh	90% CI Low	90% CI High	Stat Sig
Precriptive						
HVAC	27	$ 7,687	$ 0.0966	$ 0.0544	$ 0.1389	Yes
Lighting	163	$ 1,636	$ 0.0274	$ 0.0176	$ 0.0372	Yes
Motors and Drives	50	$ 541	$ 0.0043	$ (0.0005)	$ 0.0091	No
Refrigeration	30	$ 5	$ 0.0013	$ (0.0002)	$ 0.0028	No
Other	32	$ 28	$ 0.0039	$ (0.0002)	$ 0.0079	No
Total	*302*	*$ 1,439*	*$ 0.0274*	*$ 0.0188*	*$ 0.0360*	*Yes*
Custom						
CHP/Cogen	6	$ (12,949)	$ (0.0147)	$ (0.0247)	$ (0.0047)	Yes
HVAC	20	$ 5,584	$ 0.0240	$ 0.0003	$ 0.0477	Yes
Lighting	89	$ 5,686	$ 0.0594	$ 0.0318	$ 0.0871	Yes
Motors and Drives	42	$ 1,433	$ 0.0152	$ (0.0005)	$ 0.0309	No
Refrigeration	90	$ 1,611	$ 0.0474	$ 0.0244	$ 0.0705	Yes
Other	29	$ 15,937	$ 0.0562	$ 0.0038	$ 0.1087	Yes
Total	*276*	*$ 4,454*	*$ 0.0368*	*$ 0.0231*	*$ 0.0506*	*Yes*
Gas measures	**n**	**Average Annual NEI per Measure****	**NEI/Therm**	**90% CI Low**	**90% CI High**	**Stat Sig**
Prescriptive						
Building Envelope	2	$ 1,551	$ 3.6151	$ 2.6418	$ 4.5885	Yes
HVAC	50	$ 755	$ 1.3464	$ 0.5433	$ 2.1496	Yes
Water Heater	47	$ 129	$ 0.2604	$ (0.0012)	$ 0.5221	No
Total	*99*	*$ 439*	*$ 0.8344*	*$ 0.3634*	*$ 1.3053*	*Yes*
Custom						
Building Envelope	46	$ 922	$ 0.4774	$ 0.1258	$ 0.8290	Yes
HVAC	41	$ 2,798	$ 0.2291	$ 0.1522	$ 0.3060	Yes
Water Heater	23	$ 803	$ 0.1824	$ (0.4953)	$ 0.8601	No
Other	2	$ 1,905	$ 0.5253	$ (5.6577)	$ 6.7083	No
Total	*112*	*$ 1,940*	*$ 0.2473*	*$ 0.1490*	*$ 0.3455*	*Yes*

*Equals (NEI/kWh) x (Average annual kWh)
*Equals (NEI/therm) x (Average annual therms)

Prescriptive electric. HVAC measures showed the highest estimated NEI (NEI $0.097/kWh), while lighting showed the second highest NEI both in terms of NEI/kWh ($0.03/kWh) and average NEI ($1,636 per measure).

Prescriptive gas. Building envelope showed the highest estimated NEI/therm ($3.62/therm), which also resulted in the largest average NEI ($1,551 per measure). HVAC measures showed the second highest NEI both in terms of NEI/Therm (1.35/therm) and average NEI ($755 per measure).

Custom electric. Lighting showed the highest NEI in NEI/kWh ($0.06/kWh) and highest average NEI ($5,686 per measure). NEIs for cogeneration showed negative results because the energy efficient equipment required increased preventative maintenance and increased administrative costs.

Custom gas. HVAC showed the highest estimated average NEI ($2,798 per measure). Building envelope had the second highest estimated average NEI ($922 per measure) and the highest NEI/therm ($0.47/therm).

1.2.2 Relationship between NEIs and Program Attribution

DNV KEMA used program attribution, NEI expectation information, and the realized non-energy impacts to examine differences in attribution rates between participants who realized NEIs and those who did not report NEIs. However, our analysis did not provide conclusive evidence that NEIs and attribution (as estimated using the FR/SO study method) were correlated. However, some of the data suggested that this finding may have been due to the consistently high attributions from the FR/SO study.

1.2.3 Like and Unlike Spillover

Only a few respondents provided sufficient measure descriptions to estimate spillover savings. Therefore, results of the spillover analysis were restricted, reporting the percent of respondents who claimed to have installed measures of the same type (like spillover) and of a different type (unlike spillover) at one of their facilities.

The results suggested that Massachusetts energy efficiency programs did result in substantial unlike spillover. Between 10% and 25% of measures resulted in some type of energy efficiency measure being installed without program support. The results demonstrated the importance of considering purchase decisions made across multiple locations of an organization when estimating spillover. Further, the relatively high incidence of unlike spillover suggested opportunities for cross selling programs not yet realized by the PAs.

1.3 RECOMMENDATIONS

DNV KEMA has the following recommendations based on this study's research, analysis and conclusions:

- National Grid and NStar should use the measure mappings provided in Appendix G to apply the appropriate NEIs to their existing programs. The remaining PAs should use the gross NEI per kWh and therm savings estimates presented in Table 1-2 to estimate NEIs, provided estimates were statistically significant. For measures corresponding to non-significant NEI estimates, the PAs should use $0.
- PAs should continue their current practice of applying the attribution rate used for estimating net energy savings to estimate net NEIs. We did not find sufficient evidence to justify altering this approach. We recommend further study of this relationship.
- DNV KEMA recommends further study of unlike spillover. Evidence provided by this report suggests high potential for unlike savings, particularly among multiple location companies. However, such a study will require more a focused engineering based approach to obtain the necessary engineering parameters needed to estimate savings.

The study should also account for spillover resulting from measures installed across multiple locations.

- The PAs should continue to promote NEIs in program marketing, as their current efforts appear to be effective in driving awareness of NEIs as a source of value. Data obtained for this NEI study may provide valuable insights into key touch points for account managers promoting the programs.
- The NEI study was able to provide some evidence for resource NEIs. Capturing these effects directly in program tracking data or through on-site interviews would be best.

1.4 LIMITATIONS TO THE APPROACH

- This study was primarily focused on estimating monetary NEIs associated with C&I programs. While the evaluation team did capture information pertaining to resource savings, we did not obtain sufficient data to obtain statistically reliable resource savings estimates.
- Spillover information obtained through this study was not sufficient to quantify like and unlike spillover savings associated with program measures. This is largely due to the level of complexity in the NEI interview itself, which required individuals with extensive knowledge of the business impacts associated with the installed measures. These individuals often did not have knowledge of the engineering specifications needed to estimate spillover.

  Our analysis indicated that it is important to consider technology purchases across all locations of a company when examining spillover, rather than looking at each location separately. Investment decisions in one location frequently influence subsequent decisions at other locations. Conducting spillover analysis at the facility level can result in ignoring spillover from additional locations.
- Our research approach focused primarily on identifying annual NEIs. Consequently, the results may under estimate NEIs associated with one-time costs or benefits.
- The NEI estimates provided by this study were largely influenced by O&M cost reductions. In a number of instances this change in O&M costs resulted from decreased repair costs associated with the new, high efficiency (high quality) equipment. Due to number of assumptions required to depreciate the installed equipment and amortize the cost differential, our estimates assumed that this cost differential occurs annually, over the life of the equipment. This may over estimate NEIs associated with older measures. Further research is required to examine the appropriate treatment of NEIs associated with maintenance over time.
- NEIs may be underestimated simply due to the nature of self report surveys. Survey respondents were frequently able to identify NEIs, but we found that, for the same measure type, some did and some did not see the same NEIs across multiple respondents. For example, labor costs associated with less frequent changing of light bulbs were an NEI we would expect to find at most sites. While this was cited frequently,

many sites either did not experience this impact, or it did not occur to them during the survey despite probing.

- There was an increased chance of self selection bias because much of the sample consisted of people who agreed to be interviewed twice. This was true for all of the prescriptive measures and many of the custom measures.
- The following factors may limit the applicability of NEI estimates in other jurisdictions:
    - Values were specific to Massachusetts customers. For example the general cost of labor in MA may be higher than that in a Midwestern state.
    - The mix of measures assumes C&I programs that are retrofits, which consisted of a mix of early replacement and replace on failure measures. Additional steps should be taken to address new construction.
- The following limitations apply to the applicability of this research to future years:
    - The confidence intervals reported do not correct for the 2010 population size.
    - Significant program changes in terms of mix of measures, or favoring early replacement over replace on failure could make the NEI values from this study less applicable.

2. INTRODUCTION

This report presents the Massachusetts Cross-Cutting Evaluation Team's analysis of Non-Energy Impacts (NEI) attributable to the 2010 commercial and industrial (C&I) retrofit programs administered by the Massachusetts Program Administrators (PA).

DNV KEMA conducted in-depth telephone interviews with 505 participants representing 789 measures. The self-reported responses to the in-depth interviews covered prescriptive and custom measures for both electric and gas measures. For electric measures, we report the average NEI per kWh savings, and average NEI per therm savings for gas measures. The evaluation team also examined the relationship between NEIs and program attribution, and estimated the incidence of spillover.

2.1 RESEARCH OBJECTIVES

The overall goal of this Non-Energy Impact study was to provide a comprehensive set of statistically reliable NEI estimates across the range of C&I retrofit programs offered by the Massachusetts electric and gas PAs.

DNV KEMA identified the following objectives for this study:

1. Quantify NEIs – We estimated NEIs for commercial and industrial retrofit projects completed in 2010. We estimated gross NEIs per unit of energy savings resulting from both prescriptive and custom electric and gas measures separately.
2. Examine the relationship between NEIs and program attribution – We examined the attribution rates of individuals who did and did not realize NEIs to inform the appropriate attribution rate for computing net NEIs. This analysis focused on examining differences in attribution rates for NEIs rather than re-estimating the free-ridership rates presented in the 2011 free-ridership and spillover (FR/SP) study.
3. Identify incidence of spillover – We distinguished two types of spillover: like and unlike. **Participant spillover** was defined as energy savings resulting from program-influenced installation of energy efficiency measures that did not receive program incentives. We defined **like spillover** as energy savings resulting from program-influenced installation of energy-efficient equipment of the same type (i.e. the same measure, capacity, and efficiency level). **Unlike spillover** reflected energy savings resulting from program-influenced installation of energy-efficient equipment of a different type (i.e., different measure, capacity, or efficiency level).

2.2 BACKGROUND

The evaluation team embarked on this study to fulfill the directive set forth by the State's Department of Public Utilities (DPU) to update and improve non-energy impact estimates for use in the PA's 2013 to 2015 energy efficiency three-year plan and future annual plans. In addition, the PAs will use this study to assist in program marketing, as NEIs increase the value proposition of energy efficiency programs for participants.

The results of the NEI analysis will be used to assess the cost effectiveness of the C&I programs in Massachusetts. In 2010, the DPU approved use of NEIs in the energy efficiency three-year and annual plans, but directed the PAs to provide more current and comprehensive evidence of NEIs:

> *"We approve the evaluation, measurement, and verification plans proposed by the Program Administrators. However, we direct them to evaluate their assumptions regarding non-electric benefits, avoided transmission and distribution costs, and savings associated with oil heat efficiency measures in order to develop more up-to-date and well-documented estimates for future planning purposes…*

> *"The Attorney General urges the Department to require that the Program Administrator support non-gas non-resource benefits included in their cost-effectiveness analyses with actual claimed results, recent studies, actual field validations, and independent third-party audits (Attorney General Brief at 27). The Program Administrators indicated that they intend to evaluate non-gas benefits, including non-resource benefits, during the course of the Three-Year Plans (Exh. Common 2, at 257; Tr. 3, at 461-462). In Section V.C, above, the Department expressed concern regarding the reliability of non-gas non-resource benefits, noting that the Program Administrators themselves accept that at least some of the categories of non-resource benefits claimed in their Three-Year Plans are lacking in recent and thoroughly-reviewed support documentation"*[6]

Therefore, the primary motivation for this cross-cutting NEI research effort was to obtain the necessary information to incorporate NEIs into the PA's next 2013–2015 three-year plan. In addition, the PAs and EEAC consultants expressed interest in using this NEI research to assist in program marketing efforts.

In the following subsections, we define NEIs and discuss their application in the design, evaluation, marketing, and implementation of energy efficiency programs. We discuss the state of NEI research prior to this study, the advantages and shortcomings of that research in fulfilling the PAs current research needs, and identify how the current research was designed to fill those gaps.

2.2.1 Definition of NEIs

Non-Energy Impacts (NEIs) include positive or negative effects attributable to energy efficiency programs apart from energy savings. Non-energy benefits (NEB) frequently refer to positive NEIs, while negative NEIs—non-energy costs— reflect ways that energy efficiency measures result in adverse effects. NEIs (or NEBs) are further distinguished into participant and societal NEIs.

> *"Participant benefits (or NEIs)* are monetary and non-monetary benefits (positive or negative) that directly benefit a program partner, stakeholder, trade ally, participant, or the participant's household." Examples include lower operations and maintenance costs, or increased sales or revenue."[7]

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[6] The Commonwealth of Massachusetts. DEPARTMENT OF PUBLIC UTILITIES. January 28, 2010. D.P.U. 09-121 through D.P.U. 09-128. http://www.env.state.ma.us/dpu/docs/gas/09-121/12810dpuord.pdf

[7] Hall, Nick, Jeff Riggert, and Tom Talerico. TechMarket Works. *Focus on Energy Statewide Evaluation Non-Energy Benefits Cross-cutting Report: Year 1 Efforts*: *Focus on Energy*." State of Wisconsin Department of Administration Division of Energy. January 30, 2003.

Societal benefits (or NEIs) are "those that benefit society at large and can be provided via monetary savings to the energy provider that can be passed on to the society at large via energy price reductions or lower price increases, or benefits that directly benefit the society at large." [8] Examples include reduced carbon emissions and lower water treatment costs.

This report focuses on participant NEIs for C&I customers only. Residential NEI estimates were presented to the PAs in an August 2011 report.[9]

2.2.2 Applications of NEIs

Estimating NEIs provides utilities, regulators, and customers with valuable information when designing, promoting, implementing and evaluating energy efficiency programs. Hall et al (2003) reviewed the current and potential uses of NEIs by these groups. They identify several applications of NEIs, including the following:

- Program marketing /targeting – Positive NEIs represent opportunities for customers to decrease costs for maintenance, administration, and waste management. Similarly, NEIs identify sources of increased revenues from added sales or production increases, as well as increased amenities such as improved lighting conditions, reductions in noise pollution, or an intrinsic desire to "do the right thing." Program implementers and utilities can use information provided by NEI research to help promote energy efficiency programs and target customers who are most likely to realize such benefits.
- Benefit/cost analysis (BCA) for customers – Potential customers (particularly C&I customers) use BCA to evaluate capital investment decisions, such as the installation of new energy efficiency equipment. Whether customers conduct a formal BCA, or they intuit the result based on intricate knowledge of their business, positive NEIs offer additional information that implementation contractors and utilities can offer into this decision making process. Documented positive NEIs provide valuable information for BCA tests performed by customers, allowing them to off-set capital investment costs with benefits derived from reduced operations and maintenance, administrative, or waste handling costs, or added sales and revenue. Positive NEIs have the potential to reverse the results of a BCA for C&I customers in cases where the energy savings alone provide minimal to marginal net benefits.
- Program refinement – Understanding what NEIs may or may not result from a program can help inform the PAs in their design.
- Portfolio development – Centralized agencies are concerned with the overall economic impact on their society across a range of programs. While some programs may not represent substantial energy savings alone, they may provide greater societal benefits. NEIs offer important information regarding societal impacts, or externalities that may reflect a more accurate accounting of the overall impact of EE programs on the state than energy savings alone.

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[8] Hall, et al. 2003. (Senergy efficiency footnote 3.)
[9] NMR. *"Massachusetts Special and Cross-Sector Studies, Residential and Low-Income Non-Energy Impacts Evaluation." Prepared for the: Massachusetts Program Administrators. August 15, 2011.*

- Regulatory cost-effectiveness testing – A more recent application of NEIs is for Total Resource Cost models used in regulatory filings, such as annual and energy efficiency three-year plans filed by PAs with regulatory agencies.

2.2.3 Existing NEI research for Massachusetts energy efficiency programs[10]

While there is a wealth of literature surrounding NEIs, there is fairly limited current NEI research specific to Massachusetts-based C&I programs. The following two studies discussed in this section are the most current and directly applicable to the PA's C&I Energy efficiency programs.

TecMarket Works (2007)[11] – This study used a survey based approach to obtain self-reported non-electric benefits to custom measure programs. The study made a number of improvements over much of the existing survey based NEI research effort. First, it separated NEIs into mutually exclusive business impacts that may result from the installation of energy efficiency measures. The authors first used closed-ended questions to determine whether respondents experienced changes to any of the business areas. This allowed respondents to distinguish cost and revenue impacts derived from separate business areas such as operations and maintenance, material handling, administration, and waste management. The study then used open ended questions to obtain quantified NEI estimates. The study also focused considerable attention on handling extreme values for NEIs.

However, several of the current research needs were not addressed by this study. First, the TecMarket Works study focused on custom non-electric impacts only, while the current research objectives focused on NEIs associated with prescriptive and custom electric and gas measures. Second, the study resulted in many missing ("don't know") responses to the open ended self reported valuation questions. We speculated that this is due to the obscure nature of non-electric benefits. While respondents were aware that "things changed" when a measure was installed, absent detailed probing regarding the nature of those changes, respondents likely found it too difficult to quantify. A third limitation of this study was the relatively limited sample size, which contributed to a lack of statistically significant results. Finally, this study did not address questions pertaining to energy efficiency program attribution and NEIs.

Optimal Energy (2008)[12] – This study provided non-electric benefits associated with prescriptive C&I electric programs in Massachusetts. Using an engineering based approach, this study estimated cost changes resulting from newly installed lighting and energy management system (EMS) equipment. The benefit of this approach was that it clearly defined and documented the specific sources for cost savings resulting from the installed measures.

However, due to the complexity in modeling, the study used a more conservative approach to quantifying NEBs by assuming values of zero for all measures except those associated with

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[10] While a full literature review is outside the scope of this study, we provide a brief review of existing NEI research employed by the PAs.

[11] TecMarket Works. "*Non-Electric Benefits from the Custom Projects Program: A look at the effects of custom projects in Massachusetts*" Prepared for: National Grid. Roth, Johna and Nick Hall. September 25, 2007.

[12] Optimal Energy, Inc. *C&I Prescriptive Non-Electric Benefits. Wyatt, Francis. August 22,2003.*

prescriptive lighting and EMS measures. Further, custom measures were not addressed. This study also did not attempt to address questions pertaining to program attribution and NEIs.

The present study incorporated elements from each of these studies in order to further the evolution of NEI research. Our approach uses self reported responses to a series questions to derive estimates of the same mutually exclusive NEI categories developed by Roth and Hall (2007). We then expanded the sample size to nearly 800 measures across prescriptive and custom EE programs. We then designed used trained energy industry analysts to conduct in-depth interviews rather than a standardized survey. This allowed interviewers to probe deeply into potential sources of NEIs, in order to extract information used to estimate NEIs, similar to the engineering based approach used in the Optimal Energy study. These probes allowed respondents to express the NEIs in terms with which they are failure (i.e. number of hours saved to change light bulbs and wages) rather than requiring them to approximate a value to an abstract concept such as the impact of EE lighting on operations and maintenance costs. The combination of these factors lead to the development of robust set of NEI estimates presented in this report.

2.3 ORGANIZATION OF REPORT

This report is presented in the following sections:

Section 3 – Discusses the methodology used in this study;

Section 4 – Presents the study results;

Section 5 – Provides conclusions, recommendations, and limitations of the study;

Appendix A Prescriptive measure sampling plan;

Appendix B Custom measure sampling plan;

Appendix C Detailed weighting approach;

Appendix D Prescriptive Measure Interview guide; and

Appendix E Custom Measure Interview guide.

3. METHODOLOGY

The NEI Study was based on survey data collected from a sample of 2010 C&I program participants for prescriptive and custom as well as electric and gas measures. The primary source for the sample frame was the pool of respondents to the 2011 Massachusetts free-ridership and spillover study, which allowed the evaluation team to examine the relationship between program attribution and NEIs.[13] [14] Drawing on the lessons learned from both the TecMarket Works and Optimal Energy Research, we conducted a large scale in-depth interview (IDI) effort to provide statistically significant NEI estimates across program type (prescriptive and custom) and fuel types (electric and gas) by measure category.

The evaluation team based NEI estimates on survey responses from the same group of participants used in the 2010 participant FR/SO study. This allowed us to examine the appropriate level of attribution to apply to NEIs relative to the attribution rates on energy savings. While providing revised free ridership rates for NEIs was not within the scope of this study, our analysis did provide valuable insight into the appropriate level of attribution when applied to NEIs, an issue clearly identified in the NEI literature.[15]

The research instrument separated NEIs into mutually exclusive groups and used a series of open ended questions to determine NEI values. Experienced energy industry analysts collected information about the costs and benefits incurred by the customer at their facility's business operations. This technique allowed respondents to provide specific valuations of each NEI category across all electric and gas prescriptive and custom measures, reduced the number of "don't know" responses, and documented the sources of value to the respondent by identifying the specific cost and revenue changes that occurred as well as obtaining metrics to measure the magnitude of those changes.

3.1 OVERVIEW OF APPROACH

The key components of the methodology were as follows:

- Selected sample for telephone interviews with 2010 Massachusetts C&I custom and prescriptive energy efficiency program participants;
    - For prescriptive measures, selected the sample from the 1,499 measures completed by the 2010 participant FR/SO2010 participant FR/SO survey;
    - For custom measures, conducted surveys with the 258 measures from the 2010 participant FR/SO2010 participant FR/SO survey, and supplemented this sample with 2010 custom program participants who did not complete FR/SO surveys;
- Designed the research instruments, trained the interview staff, and oversaw quality control;
- Experienced DNV KEMA energy analysts conducted the semi-structured interviews;

[13] 2010 Commercial and Industrial Electric Programs Free-ridership and Spillover Study: Final Report. Prepared for the Massachusetts PAs. Prepared by TETRA TECH. July 26, 2011.

[14] 2010 Commercial and Industrial Gas Programs Free-ridership and Spillover Study: Final Report. Prepared for the Massachusetts PAs. Prepared by TETRA TECH. September 20, 2011.

[15] Skumatz, Lisa A. Ph.D., M. November 2009. See Footnote 7

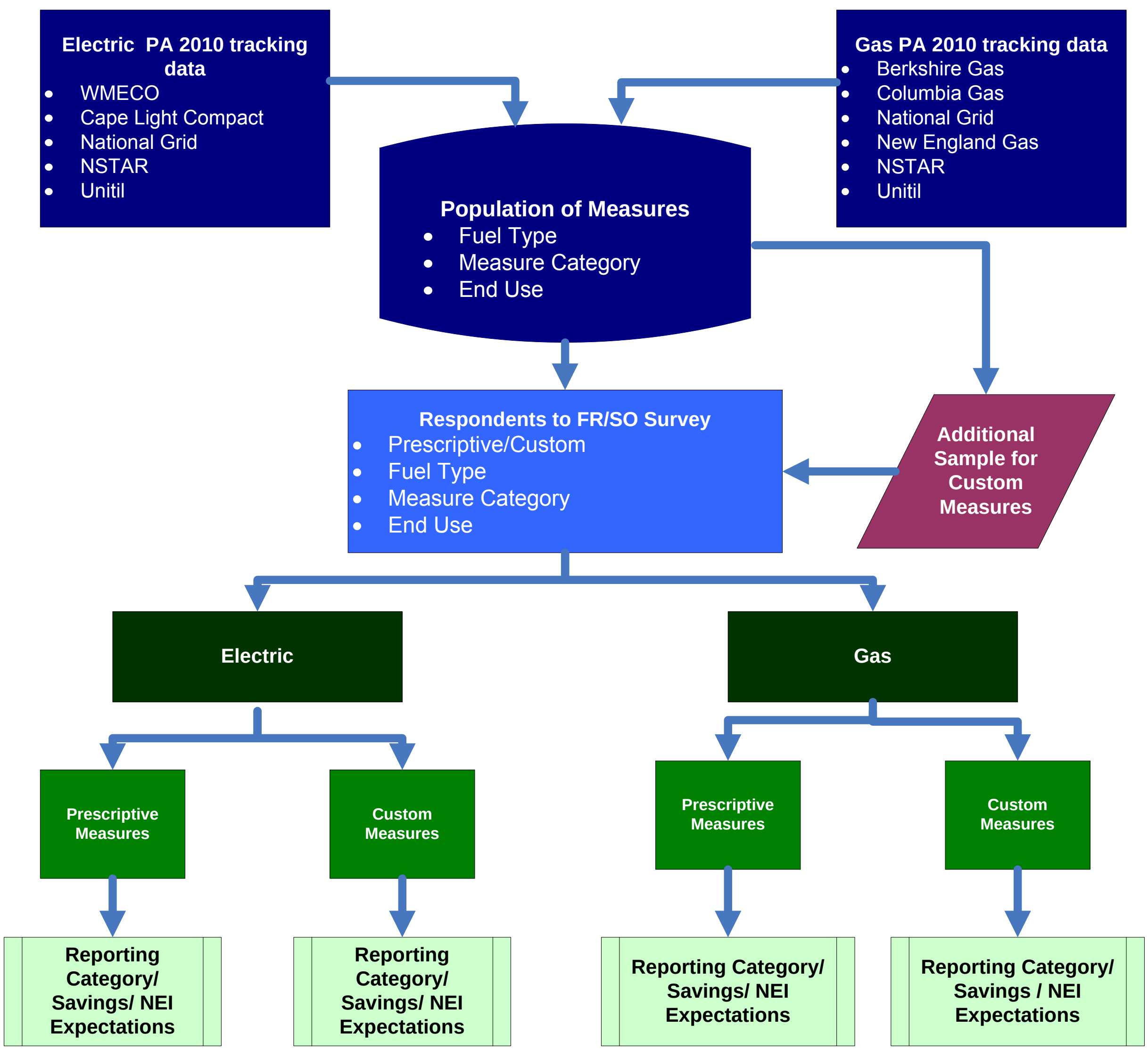
- Collected data on NEI types and dollar values, and like and unlike spillover.
- Calculated NEIs by reporting measure categories;
- Estimated like and unlike spillover; and
- Combined NEI survey results with 2010 participant FR/SO2010 participant FR/SO survey results to examine the relationship between NEIs and program attribution.

3.2 SAMPLE DESIGN

This section presents a summary of the prescriptive and custom measure sampling plans. Detailed plans for the prescriptive and custom measure sample designs are provided in Appendix B and Appendix C, respectively.

Figure 3-1 depicts our sampling approach for this NEI study.

Figure 3-1 Sample Frame Overview: Prescriptive and Custom Measures



3.2.1 Prescriptive Measure Sample Design

For the prescriptive measure NEI sample, the population frame was the projects included in the 2010 participant FR/SO study. Following the same group of respondents allowed the evaluation team to examine linkages between expected[16] and realized NEIs, and the relative influence of program marketing on expected NEIs. Moreover, we were able to assess potential differences in the free-ridership rates of those who expected and realized (experienced) NEIs from those who did not expect and/or realize NEIs. A sample of 450 sampled prescriptive measures (297 electric and 153 gas measures) were selected from the population of 1,499 prescriptive measures.

Electric sample

The number of completed interviews targeted for each of the NEI Study reporting groups[17] is presented in Table 3-1. The overall level of precision was expected to range between 9% (assuming an error ratio of 1.0) and 15% (assuming an error ratio of 1.6).

Table 3-1 Expected Precisions – Prescriptive Electric Scenario 3: Recommended Approach

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
Lighting	769	128	77%	11%	18%
Motors and Drives	124	67	13%	7%	21%
HVAC	62	38	5%	16%	34%
Other	336	64	5%	31%	51%
Overall	**1,291**	**297**	**100%**	**9%**	**15%**

* Optimistic precisions assumed an error ratio of 1.0 and used an expected response rate of 2/3 in the reporting groups where we took a census, while the conservative precisions assumed an error ratio of 1.6 and a response rate of 1/2 in the reporting groups where we took a census.

Gas sample

We recommended taking a census of gas prescriptive measures in order to maximize the statistical precision of NEI estimates. We estimated that a census of measures would provide between 9% and 15% overall relative precision depending on the expected number of completed surveys achieved and the observed variance in responses. Table 3-2 presents the target number of completed interviews and the estimated relative precisions based on taking a census of all gas measures completed in the 2010 participant FR/SO study.

[16] Data to estimate expected NEIs were gathered at the same time as part of the FR/SO study.
[17] We use the term reporting group to refer to collapsed electric end use categories and gas measure categories.

Table 3-2 Expected Precisions – Prescriptive Gas Scenario 2: Recommended Approach

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
HVAC	116	77	51%	11%	18%
Water Heater	109	73	46%	15%	24%
Other	4	3	3%	103%	167%
Overall	**208**	**153**	**100%**	**9%**	**15%**

* Optimistic precisions assumed an error ratio of 1.0 and used an expected response rate of 2/3 in the measure groups where we took a census, while the conservative precisions assumed an error ratio of 1.6 and a response rate of 1/2 in the measure groups where we took a census.

3.2.2 Custom Measure Sample Design

DNV KEMA sampled a census of the participants who installed custom measures that were also included in the 2010 participant FR/SO study. We supplemented this sample with additional measures from the population of custom measures from the PAs 2010 tracking data in order to obtain better precision in our estimates.

Electric sample

Table 3-3 illustrates the target number of completes and the expected precision levels for the custom electric sample for each 2010 participant FR/SO Reporting Groups. The sample size and distribution targeted a relative precision of 80% confidence +/-10% precision levels for each reporting category based upon an assumed error ratio of 1.2. For some measure categories, including the building envelope, CHP/Cogeneration, Compressed Air, Process and Comprehensive categories, the samples sizes were too small to attain the 80% confidence +/-10% precision levels.

Table 3-3 Expected Precisions – Custom Electric Sample by 2010 participant FR/SO Reporting Group

2010 participant FR/SO Reporting Group	Pop Measures**	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop kWh	Optimistic Precision at 80% Confidence	Conservative Precision at 80% Confidence
Building Envelope	5	1	3	0%	57%	76%
CHP/Cogen	15	5	11	11%	15%	41%
Compressed Air	15	6	10	5%	11%	33%
HVAC	110	36	48	28%	10%	13%
Lighting	320	79	91	25%	10%	13%
Motors and Drives	84	26	39	10%	10%	15%
Process	21	11	15	6%	16%	34%
Refrigeration	284	73	80	8%	10%	14%
Other	27	8	13	7%	26%	36%
Overall	**881**	**245**	**310**	**100%**	**5%**	**8%**

* Optimistic precisions assumed an error ratio of 1.2 and used an expected response rate of 2/3 in the measure groups where we took a census, while the conservative precisions assumed an error ratio of 1.6.

** For custom measures we also show the population of measures to illustrate the additional sample frame available for selecting the subsequent custom measure sample.

Gas Sample

Table 3-4 presents the target number of completed interviews and expected precisions at the 80% confidence level for the custom gas sample for each 2010 participant FR/SO Reporting Group.

Table 3-4 Expected Precisions – Custom Gas Sample by 2010 participant FR/SO Reporting Group

2010 participant FR/SO Study Reporting Group	Pop Measures **	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Therms	Expected Precision at 80% Confidence	Conservative Precision at 80% Confidence
Building Envelope	82	7	52	6%	13%	17%
HVAC	170	39	66	74%	10%	13%
Water Heater	55	23	22	8%	48%	64%
Process	9	37	6	8%	28%	37%
Other	8	0	5	5%	30%	41%
Overall	**324**	**106**	**151**	**100%**	**8%**	**11%**

* Optimistic precisions assumed an error ratio of 1.2 and used an expected response rate of 2/3 in the measure groups where we took a census, while the conservative precisions assumed an error ratio of 1.6.

** For custom measures we also show the population of measures to illustrate the additional sample frame available for selecting the subsequent custom measure sample.

3.3 INTERVIEW GUIDE AND ADMINISTRATION

The evaluation team's approach to instrument design and administration were critical factors in developing robust NEI estimates from self-reported interview responses. In-depth interviews provided interviewers with the flexibility to probe for differing business impacts resulting from the installed measures. We structured our research instrument to provide interviewers with the needed flexibility, while maintaining consistency in the data collected. Using energy industry experts to conduct interviews allowed us to probe more deeply to identify the specific relevant business impacts. Interviewers were familiar with how the installed measures may impact a facility. Because of the interdependency between instrument design and data collection, we describe both activities in this section.

3.3.1 Instrument Design

DNV KEMA developed two separate interview guides for the prescriptive and the custom measures. The guides included the following sections:

1. Introduction and Screening. This section verified we had the proper respondent on the phone and introduced the survey.
2. Equipment Verification. This section verified that the rebated equipment was still installed. If not, it attempted to learn what happened and if the rebated equipment was replaced by other equipment.
3. Free-ridership (Custom measures not surveyed previously as part of the FR/SO study only). This section asked the respondent if the program incentives or assistance affected the timing, efficiency, or quantity of the equipment they installed. These respondents did not have a corresponding attribution rate to apply to spillover estimates obtained through this study, while customer included in the FR/SO study did have attribution rates available.
4. Non-Energy Impacts. This section asked respondents whether their company had experienced any non-energy impacts from the rebated equipment. The NEIs were divided into costs and revenues, which were then each divided into several categories and sub-categories. The purpose of this division was to help guide respondents through the process of estimating NEIs. The categories and questions were based on categories used in the 2007 TecMarket Works non-electric benefits questionnaire. DNV KEMA reworded and reordered the questions to improve flow and to reduce the likelihood of double-counting.
5. Spillover. These questions assessed whether the respondent's company installed any non-rebated energy efficiency measures since participating in the program in 2010.

In the early stages of implementing the custom survey, DNV KEMA determined that many respondents had both prescriptive and custom measures. For these participants, interviewers relied on a unified interview guide with skip instructions to guide the respondents to the relevant sections. Copies of the final in-depth interview guides used for both prescriptive and custom measures are included in Appendix D and Appendix E.

NEI Questions

The NEI question battery focused on 13 categories, as presented below. The questions were structured to prevent possible double counting across categories by presenting related categories sequentially (e.g. three and four) for easier respondent recall. In addition, the interviewer protocols were designed to confirm that costs or savings included in one category were not included in any other categories.

1. Operations and maintenance costs, including associated labor and parts for both contractors and in-house staff.
2. Administrative labor refers to the company's time costs from the back office people, such as accounting.
3. The cost of supplies, materials and materials handling. The survey defined this NEI category as: "Time and costs for people in the loading docks and warehouses."
4. Transportation or materials movement costs including time, fuel costs, vehicle costs, wages.
5. Other labor costs - other labor at the company not covered in O&M, Administration, Materials Handling, or Materials Movement categories.
6. Water usage, including the amount of fresh water or processing water used and waste or discharge water. Water savings was an NEI of specific interest to the Massachusetts PAs. In addition, many of the gas-saving measures, such as pre-rinse sprayer valves, save energy by simultaneously saving water.
7. The amount of product spoilage or defects.
8. Waste disposal costs.
9. Fees including insurance, inspections, permits and legal fees.
10. Other costs. This category was to ensure that we recorded all of the cost changes that resulted from installation of the new measure.
11. Sales. This was intended to capture basic revenue changes resulting from the new measures. These could occur as indirect results of the new measures. For example, new lighting might improve visibility in a company's showroom and increase sales. Or, being more energy efficient could be reflected in the company's advertising and increase business from people trying to be environmentally sensitive.
12. Rent revenues.
13. Other revenues.

When NEI sources were determined, the evaluation team used additional closed ended questions to assess whether the respondent experienced an increase or decrease in each affected NEI (e.g., an increase or decrease in operations and maintenance costs). Next, we used open ended questions to ask respondents to provide the overall dollar impact associated with each NEI category.[18] Because many respondents were unable to provide overall NEI estimates outright, the interviewers guided respondents through a series of structured probes to determine whether respondents experienced any changes to various cost or revenue centers associated with each NEI category. For example, internal labor and external labor are separate cost centers associated with Operation and Maintenance (O&M) costs. Once the interviewer identified the impacted cost and revenue centers, deeper probes were used to determine the nature of those changes and specific metrics for quantifying the impact. O&M costs consist of internal and external labor costs, as well as parts and supplies, and training. If a respondent indicated a measure affected their O&M costs, the interviewer asked another series of questions to obtain the necessary information for imputing a value. In this case, if the respondent indicated that the installed measure decreased labor costs, we asked them to estimate the number of hours that labor was reduced and the loaded or un-loaded cost of that labor. In some cases, respondents were not capable of providing values at this level of detail (hours of labor or wages). In these cases, the interviewers used additional probes that allowed the evaluation team to impute values. This approach improved upon previous NEI survey efforts by having the interviewers work with respondents to help them monetize the NEIs and ensure that the respondent thought about the various sub-categories that could apply to an NEI. This provides a more robust estimate than respondents' initial top-of-the-head estimate or a "don't know."

Table 3-5 presents the general probes for each NEI section. The goal of these probes was to quantify the NEIs of each measure into the monetary and resource impacts of the installed measures.

[18] For resource savings (fuel and water) we obtained estimates of the quantity of resource saved. Where respondents were only able to provide the monetized value of resource savings, we used this information, along with average resources prices, to estimate the resource savings, and excluded the value of that savings from monetized NEI estimates.

Table 3-5 Non-Energy Impact Categories

NEI Category	Probes						
	Labor[1]	Parts / Materials	Training	Fuel[2]	Water	Fees / Permits	Other
Operations & maintenance	✓	✓	✓	✓			✓
Administration	✓		✓				✓
Materials handling	✓						✓
Materials movement	✓	✓		✓			✓
Other labor	✓		✓				✓
Spoilage/Defects	✓	✓					✓
Water usage					✓		
Waste disposal	✓	✓				✓	✓
Fees						✓	✓
Other costs							✓
Sales							✓
Rent revenues							✓
Other revenues							✓

[1] Labor included internal and external labor and included probes for assessing fully loaded costs.
[2] Fuel included: natural gas, no. 2 distillate, no. 4 fuel oil, propane, wood, and kerosene.

Specific probes for each NEI category include:

Operations and maintenance costs

The interview guide included probes for internal labor, external labor, parts, training, fuel saved, and other O&M costs.

For the labor and training subcategories, the interviewers attempted to get annual hours of increase or decrease and an hourly rate. If the respondent could provide fully loaded hourly rates (including overhead, benefits, and insurance), interviewers gathered it. If the respondent could not give us exact fully loaded costs, interviewers asked for the base hourly rate and their best estimate of a multiplier to apply to that rate to impute fully loaded rates.

For parts, interviewers attempted to quantify the number and type of parts that increased or decreased, and the unit cost of each.

For training, interviewers attempted to quantify increases or decreases in training costs and whether these were one-time costs or recurring costs.

For fuel, interviewers attempted to quantify specific changes (increase or decrease) in fuel usage.

For other, interviewers asked the respondent if there were any other O&M related costs that increased or decreased that we had not yet covered.

Administrative or other labor

This section included probes for internal labor, external labor, training, and other. The use of these specific probes was similar to their descriptions in the O&M section, except they were applied to administrative rather than O&M costs.

Cost of supplies, materials and materials handling

This section included probes for internal labor, external labor, and other. The use of these probes was similar to their descriptions in the O&M section, except they were applied to materials handling rather than O&M costs.

Transportation or materials movement costs

This section included probes for internal labor, external labor, fleet service and parts, fuel, and other. Except for being applied to transportation and materials movement's costs, these probes were used in a similar way as in the O&M section.

Other labor costs

This section included probes for internal labor, external labor, training, and other costs. The probes were used in the same way as for the O&M section.

Water usage

This section included probes for water usage costs, gallons of water, and wastewater.

For water usage costs, the probes attempted to identify if water usage costs increased or decreased and associate a dollar value with that change.

For gallons of water, the probes attempted to identify if water use increased or decreased and quantify it in gallons.

For wastewater, the probes attempted to quantify gallons of wastewater increased or decreased.

Product spoilage or defects

There were no specific probes for this section.

Waste disposal costs

The section included probes for waste materials, waste handling, permits, and other.

For waste materials, the probes attempted to identify the type of material (e.g. carbon dioxide, sulfur dioxide, etc.) and quantify in units the increase or decrease in emission.

For waste handling, the probes attempted to identify number of hours of labor, and the fully-loaded hourly costs for that labor, just like the internal or external labor costs in the O&M section. In the event that the respondent could not supply fully loaded hourly costs, interviewers attempted to gather enough information to allow us to impute it.

For permits, interviewers attempted to quantify in dollars the increase or decrease in pollution permitting fees incurred.

Other Fees

This section included specific probes for insurance, inspections, licenses, legal fees, and other fees. In each case, the probes attempted to quantify the increase or decrease in dollars and whether it was a one-time or ongoing change.

Other costs

There were no specific probes in this section.

Sales

This section did not include any specific probes.

Rent revenues

This section included specific probes for dollars per unit, number of units, and occupancy rates.

For dollars per unit, this probe attempted to quantify the dollar increase or decrease in rent per unit rented. It included a probe to establish the unit of measure (square feet, apartments, etc.).

Number of units attempted to quantify whether the number of units (square feet, apartments, etc.) available for the owner to rent out increased or decreased.

Occupancy rates attempted to quantify the increase or decrease in the duration of unit occupancy or vacancy.

Other revenues

There were no specific probes for this section.

Spillover Questions

In addition to NEI questions, each guide contained a series of questions to obtain data necessary for estimating like and unlike spillover. The guides contained the like spillover series from the 2011 FR/SO study. DNV KEMA added questions to address unlike spillover to estimate savings associated with these measures.

Rather than asking respondents to determine whether the additional measures were like or unlike spillover, the survey simply asked if the respondent had installed any other energy-using equipment since participating in the program. Once interviewers established the respondent installed subsequent measures, the interviewer also asked them to provide the following:

- Type of measure(s) installed;
- Efficiency level of the equipment;
- Quantity installed; and
- Whether their experiences with the rebate program, rebated measures, or contractors who did the rebated work had any effect on their decision to install the additional equipment.

DNV KEMA used this information to determine if there was like or unlike spillover for the respective end use or measure category.

Free-ridership Questions

The custom measure guide included questions used to collect program attribution information. These data were required for the portion of the custom sample that was not drawn from the 2010 participant FR/SO study's respondent pool. Because these participants were not included in the previous study, they lacked estimated program attribution scores. These scores were required to determine whether spillover estimates, also asked in this survey, were attributable to the programs.

The first version of the custom measure interview guide incorporated the same battery of free-ridership questions that was used in the 2010 participant FR/SO study. This was an attempt to keep the methodology consistent with estimates derived of that study. However, after completing a few interviews using this battery, it proved to be too lengthy to include in the NEI survey. Given the relatively limited use of the attribution questions (i.e. for spillover estimates of a small proportion of the custom measure sample), the evaluation team revised the free ridership battery to include a standard set of four questions that identified overall program attribution, plus changes to the timing, efficiency, and quantity of the installed measures. DNV KEMA has used these questions for over ten years on numerous studies, most notably for the evaluation of Wisconsin's Focus on Energy programs.

3.3.2 Survey Administration

DNV KEMA initiated the interviews on January 17, 2012 and extended data collection through May 11, 2012. The following describes procedures used for administering the survey.

Training

Senior staff provided in-person, project-specific training to all interviewers prior to data collection. The trainers reviewed the guides thoroughly with interview staff, and walked through the in-depth guide. Interviewers practiced conducting the survey with each other, and returned to the trainers to discuss any questions or problems that arose. Any interviewers added to the project at a later date received a similar training session. Interviewers were monitored closely throughout the interview process to ensure consistent questioning and reporting of results, and reported results to the survey manager daily.

The interview team consisted of recruiters and interviewers. Recruiters were responsible for identifying the appropriate contacts within each company and scheduling interviews with our trained energy analysts. Interviewers included trained experts with between three to 15 years of energy industry interviewing experience

Sample selection

The sampling unit for this study was a measure at a location. DNV KEMA's sampling approach selected a sample of measures for each of the strata identified in the sample plan presented in Section 3.2. However, customers frequently installed multiple measures, spanning various electric and gas prescriptive and custom projects. Further, there were many customers in the population that installed measures across multiple addresses, all of which tied to the same contact, company, or phone number. For these customers, we first selected the sampled measures. We then went back into the database and selected the remaining measures that linked to the sampled measure by contact name, phone number, company name, or address. We released samples to recruiters in bins selected to achieve the target number of completes across strata.

Recruiting

Recruiters sent respondents a notification letter prior to launching the study to inform them that they might be contacted within the next few months. To maximize response rates, recruiters called the sampled measures up to six times before coding all measures that linked to that respondent as a non-response. Additional bins were released once existing bins were exhausted.

A primary challenge of the survey recruitment process was identifying all of the relevant measures for each respondent. The sample data structure spanned prescriptive and custom measures for both electric and gas. To minimize the number of times customers were contacted and maximize response rates, recruiters selected all measures that linked to a single contact by either contact name, phone number, company name, or address. Recruiters then attempted to schedule a single interview across all measures the respondent could address. In some cases, recruiters were required to schedule multiple interviews with a single company to gather data for each of their installed measures.

Interview preparation

Interviewers reviewed all relevant measures for each customer prior to the interview. They then populated the in-depth interview guide with the following information to aid in the interview:

Customer identifying information – Interview contact, company/organization name, all addresses associated with that contact, telephone number, name of PA, program name, and participation date(s).

Project information –Respondents with multiple addresses could have up to two prescriptive and two custom measures sampled for each address. Interviewers reviewed the measure information for multiple site respondents to determine whether the same measures were installed across multiple facilities, or if the measures differed by location. For example, review of the tracking data helped reveal whether the upcoming interview was with a facility manager responsible for a chain of stores that all installed the exact same measures. This information was used to help reduce the interview length, as NEIs associated with duplicate measures across identical buildings could respond for the typical or average impacts across facilities.

Free-ridership – Interviewers identified whether any of the customer's measures for an upcoming interview were not selected from the pool of respondents to the 2010 participant FR/SO study. For these measures, interviewers needed to ask the free ridership sequence since attribution rates were not available through the previous study.

Spillover – Interviewers recorded all known measures for a respondent at each location. They referenced this information during the spillover section of the survey to help determine whether a measure the respondent reported as spillover actually received an incentive.

Conducting the interview

Interviewers informed respondents of the purpose of the study and identified the measure information recorded for each address associated with the contact. Next, interviewers asked the equipment verification section for the measures sampled under the reporting category. For measures that were no longer installed, the interviewer asked the respondent to provide the reason for removal. If the measure was removed due to a potentially negative non-energy impact (i.e. it made costs go up), the measure was retained for the interview. If all measures under the sampled NEI reporting category were removed, but the reason for removal was not a negative NEI, the interviewer moved onto the next NEI reporting category.

For those custom measures not included in the 2010 participant FR/SO study, interviewers then asked respondents to answer the abbreviated free-ridership battery discussed above.

Next, the interviewer cycled through the NEI sections of the interview guide for each sampled NEI reporting category at a facility. Respondents with similar measures installed across multiple locations were asked to identify facilities and measures where the NEIs were the same or similar because the structure, operations, and measures installed were the same. This helped reduce the number of times the respondent was required to cycle through the interview guide as they were able to provide a single response that represented multiple installed measures. Some respondents with multiple locations reported one set of NEIs were relevant to certain measures and facilities, while another set of NEIs were relevant to a different set of measures and facilities, even within the same NEI reporting category.

Next, the interviewer asked respondents to indicate the relevant NEI sources to explore further in the interview (e.g. operations and maintenance, or rent revenue). Once the sources of NEIs were determined, as well as the direction of those impacts (i.e. increase or decrease), interviewers guided respondents through the series of structured probes to identify the cost and revenue centers impacted, the nature of those impacts, and to obtain estimates of specific metrics needed to quantify the NEIs (e.g. frequency, time/quantity, and salary/cost) associated with each NEI category. The objective was to estimate monetary costs or benefits, so for some of these categories, our interviewers probed to convert time into money. In practice, interviewers modified probes and interview survey order based on respondent feedback, using the layered probes as guidelines only. For example, if a respondent gave full details about a measure impact at any point during the interview, the interviewer switched to more targeted, ad-hoc questions.

Data collected to estimate NEIs clustered around five major categories:

1. Respondent provided. Respondents were asked directly about any changes by NEI category, and we recorded dollars and how the estimate was derived (i.e. for example, what parts of the Operations & Maintenance costs were reduced/increased). As noted above, few respondents were able to provide reliable estimates without additional interview probes and adjustments.

2. Respondent identified NEIs and monetization. A respondent who was able to monetize the NEIs appeared straightforward, in terms of data collection. However, interviewers discovered inconsistencies, errors, and unsubstantiated results when asking how the respondent estimated the amount. For example, for the respondent who stated “I think we saved $1,000 per year on O&M,” the interviewer then asked about specific changes that may have occurred, how these changes impacted the respondent’s business, and how the cost estimate was derived. Very few respondents were able to monetize NEIs without energy analysts’ probing.

3. Respondent identified NEIs for one or more categories, but could not monetize them. Interviewers asked a series of layered probes. For example, interviewers asked if the NEI category increased or decreased (if not already answered) and then asked about cost and revenue items impacted (i.e. internal labor, external labor, parts or supplies, training, or fuel) to understand which metrics the interviewers should inquire further about.

4. Respondent did not know if there were NEIs If a respondent did not know if there were NEIs, interviewers used an interview strategy similar to the one described above. But, interviewers provided more detail and prompts, as needed, based on typical category activities. For example, lighting measure installations may have resulted in changes to the frequency of light bulb changes.

5. Respondent reported no NEIs. While the respondent who reported no NEIs also appeared straightforward, interviewers discovered that additional probes sometimes uncovered NEI impacts the respondent may not initially have considered or did not consider significant (as compared to electricity savings). For the latter, interviewers assured respondents that we wanted to capture all non-electric impacts and proceeded with the probes.

Interviewers collected spillover information at the customer level. As stated above, capturing NEI information for all relevant measures often required a single interview to span multiple measure categories across numerous addresses. A respondent's experience with a measure in one location may have influenced their decisions to install the same or different measures at separate locations. Simplifying the interview process required limiting the spillover section to the respondent level.

Recording the interview

Each interviewer entered responses into a database immediately following the interview. Responses were recorded verbatim. Where possible, they indicated the value of each NEI source, and also the values for any metrics identified through the interview. They also provided a rough formula depicting the cost or revenue impact calculation they envisioned based on the information provided. For example, the cost associated with changing light bulbs would entail the fully loaded wage times hours per year that was needed to change the bulbs.

3.4 DATA ANALYSIS

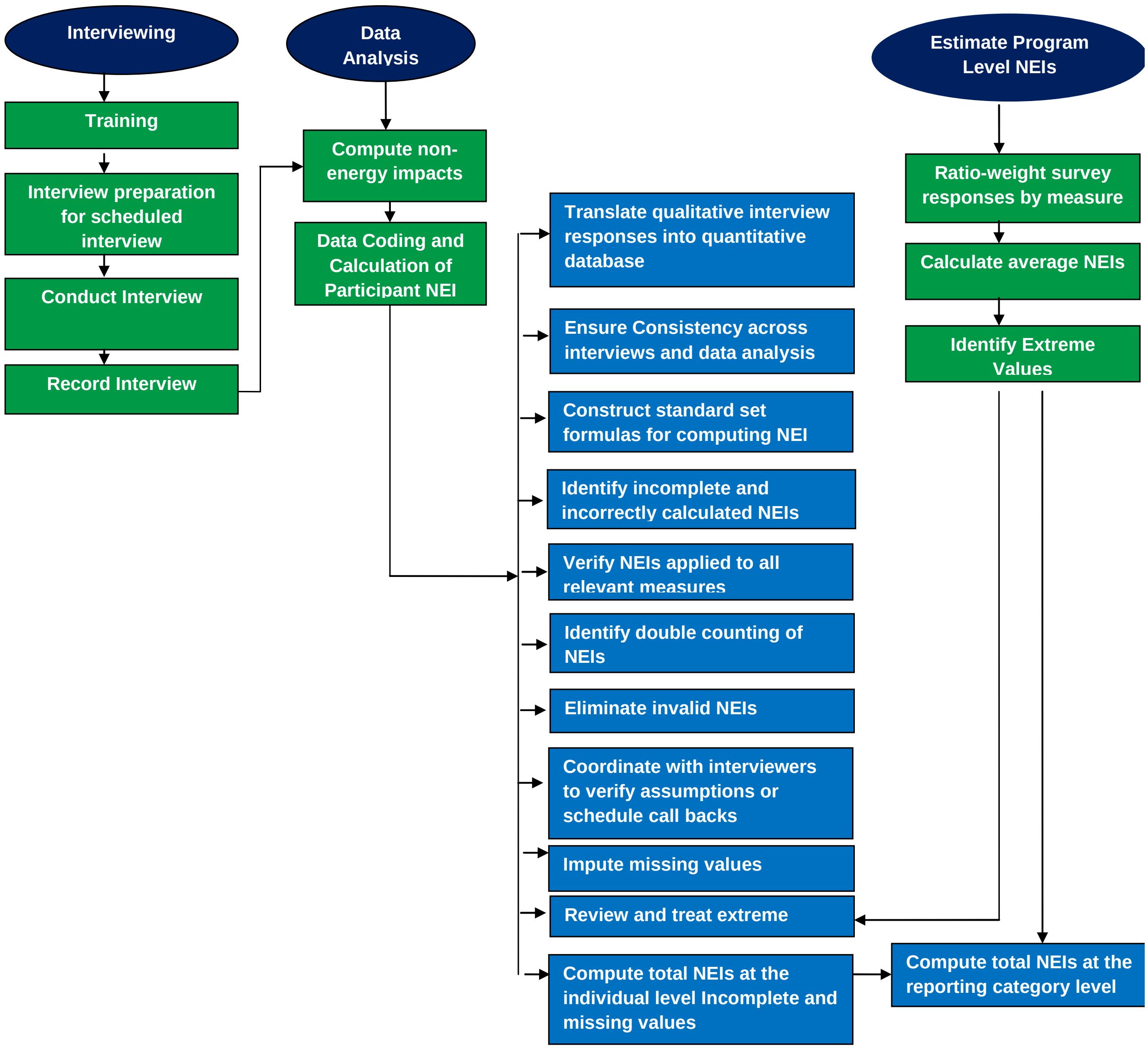
This section describes the analytical approach for computing NEIs, attribution of NEIs to energy efficiency programs, spillover, and attribution for custom measures that were not included in the 2010 participant FR/SO study.

3.4.1 Computing non-energy impacts

DNV KEMA used a multi-step process to compute NEIs associated with each measure. Figure 3-2 shows the process for computing NEIs, which began with the in-depth interview, and flowed into the data analysis process. The data analysis process and final estimation process were interrelated, as estimating average NEIs across all measures identified extreme values.

Each of the processes presented in the figure are discussed in the sections that follow.

Figure 3-2 Process for computing NEIs



Conduct Participant Interviews

During the interview process, analysts used their knowledge of the intersection of energy efficiency measures and business functions to identify an appropriate "formula" for estimating cost and benefit impacts resulting from the installed measures in relation to each specific facility. This was the first step in estimating NEIs for each measure. In order to complete this step, the interviewer was required to capture the following information during the interview itself:

- Discern the relevant cost and revenue items impacted;
- Identify the nature of those impacts; and
- Capture estimates for each parameter necessary to monetize NEIs.

Interviewers used the following basic formula to help capture the necessary information for computing most NEIs:

NEI cost change = (old equipment) – (new equipment)

Where

Cost change = increase or decrease in NEI category/activity

Old equipment = NEI activity prior to measure installation in 2010

New equipment = NEI activity after measure installation in 2010

Interviewers probed to ensure that the pre and post measure installation time periods were typical, and adjusted if necessary. For example, if a respondent said they repaired the boiler four times per year, interviewers asked further questions to verify the frequency of the equipment maintenance. On occasion the additional questions revealed that the repairs happened four times in 2009, but occurred only two times per year in previous years. This information was used to revise the initial response. This formula compared the typical year prior to and after the measure installation, typically 2009 to 2011. Table 3-6 presents the range of probes interviewers used, from general (e.g., NEI categories) to more specific (e.g., Cost/Revenue Items Impacted, Nature of Impact, and Impact Metrics). The most frequently used Impact Metrics that interviewers used to compute the NEIs were:

- Frequency – number of times activity occurred, per year, and whether it was annual-recurring or one-time;
- Time spent – internal or external labor in units of time (e.g. minutes, hours, days);
- Quantity – number of relevant staff/purchased items (e.g. employees, contractors, parts);
- Salary – labor wage, as loaded value including employee benefits; and
- Cost – total cost (or $ cost/each).

For example, if a respondent indicated that a new lighting measure required fewer bulb changes, they would then probe for the number of hours saved per bulb, times per year, number bulbs replaced, and the loaded wage. These variables were used to estimate the corresponding NEI as described in the section *Data Coding and Calculation of Participant NEIs.*

Table 3-6 Probes by NEI Category

NEI Category	Cost/Revenue Center Impacted	Nature of Impact	Impact Metrics: Occurs (# times / year)	Time (min / hrs)	Quan-tity	Salary ($/hr)[1]	Cost ($/ea.)
Operations and Maintenance	**Internal labor**	• Parts replacement • Routine maintenance • Equipment diagnostics & repair • External labor coordination • Customer calls/complaints	✓	✓	✓	✓	
	External labor	• Contractor visits	✓	✓	✓	✓	✓
	Parts / supplies	• Parts replacement • New equipment parts • Avoided parts	✓		✓		✓
	Training	• External/internal classes • Instructor labor • Training materials	✓	✓	✓	✓	✓
	Fuel Saved	• Natural Gas • Propane • No.2 Distillate • Wood • No.4 Fuel Oil • Kerosene	✓		✓		✓
Administration	**Internal labor**	• Bill handling & remittance • Administrative tasks	✓	✓	✓	✓	
	External labor	• Contracted accounting • Contracted administration	✓	✓	✓	✓	✓
Materials Handling	**Internal labor**	• Loading dock labor • Other materials handling labor	✓	✓	✓	✓	
	External labor	• Contracted load dock staff	✓	✓	✓	✓	✓
	Other	• Rental or purchased equipment • Other non-labor changes	✓		✓		✓
Materials Movement	**Fleet service/parts**	• Fleet repair/maintenance • Fleet vehicle parts	✓		✓		✓
	Fuel	• Gasoline • Electricity (plug in vehicles) • Natural gas	✓		✓		✓
	Internal labor	• Driver • Mechanic	✓	✓	✓	✓	
	External labor/services	• Contractor • Mechanic	✓	✓	✓	✓	✓
	Other	• Parking fees • Highway tolls	✓		✓		✓

[1] Includes benefits (loaded value)

(Table 3-6. Continued)

NEI Category	Cost/Revenue Center Impacted	Nature of Impact	Impact Metrics: Occurs (# times / year)	Time (min / hrs)	Quan-tity	Salary ($/hr)[1]	Cost ($/ea.)
Other Labor	**Internal labor**	• Any other labor	✓	✓	✓	✓	
	External labor	• Other contractor visits • Other external labor	✓	✓	✓	✓	✓
	Training	• External classes • Instructors • Training materials	✓	✓	✓	✓	✓
Water Usage	**Water Usage**	• Water usage	✓		✓		✓
	Wastewater	• Wastewater usage	✓		✓		✓
Product Spoilage	**Product Spoilage**	• Product/service damaged or spoiled	✓		✓		✓
Waste Disposal	**Waste Materials**	• Solid waste • Gaseous waste	✓		✓		✓
	Waste Handling	• Labor	✓	✓	✓	✓	
	Permits	• Permits/fees	✓		✓		✓
	Other	• Other costs	✓	✓	✓	✓	✓
Fees	**Insurance**	• Insurance premium change	✓				✓
	Inspections	• Equipment/facility inspections	✓		✓		✓
	Permits	• Permits (non-waste disposal)	✓		✓		✓
	Legal Fees	• Legal services • Legal filing fees	✓	✓	✓	✓	✓
Other Costs	**Labor**	• Any other labor	✓	✓	✓	✓	✓
	Non-Labor	• Non-labor costs	✓		✓		✓
Sales	**Sales**	• Change in sales revenue			✓		✓
Rent revenues	**Rent Revenues**	• Rent revenues			✓		✓
Other Revenue	**Other Revenue**	• Any other revenue changes			✓		✓

[1] Includes benefits (loaded value)

Data Coding and Calculation of Participant NEIs

The calculation of participant NEIs was based upon a thorough and rigorous review of the respondent data. DNV KEMA implemented a quality control process to ensure consistency for each participant's responses and to eliminate double counting NEIs across categories.

1. Translate the qualitative interview responses into a quantitative database

Data analysts received qualitative interview responses from the interviewers in a semi-structured text format; however, NEI computation required quantitative information. The recorded responses were entered into a database. Data analysts entered responses to the questions for each NEI category, costs and revenue items impacted, and the various metrics that were used to compute NEIs. For example, analysts entered separate fields (variables) for the total NEI dollars under each NEI category, as well as variables for the potential cost and revenue items impacted. They then recoded the specific metrics captured by the interviewer to estimate the NEI associated with that cost or revenue item.

Analysts also recorded interview notes (i.e. the text version of the interview responses) in separate fields next to the translated data fields. These text fields provided valuable information during the quality control process.

2. Ensure consistency across interviewers and data analysts

Responses to open ended in-depth interviews often varied across respondents and had the benefit of eliciting information that may not be uncovered through traditional pre-determined close-ended responses. Therefore, a primary function of the quality control process was to ensure that the data collected, and the interpretation of that data, was consistent across interviewers and data analysts. The evaluation team ensured consistency by having a second analyst responsible for reviewing all data entered, as well as verifying and standardizing data coding.

3. Construct standard set of formulas for computing NEIs

Data analysts were responsible for the quality control of the data entered by the interviewers. The data analysts identified a set of standard formulas and metrics for each cost and revenue center (i.e., the cost or revenue items) impacted under each NEI category. Standardizing the formulas across multiple measures allowed analysts to evaluate each in terms of the necessary metrics (i.e. salary, hours, price), and the range of responses to those metrics ($/hour). Table 3-7 presents the standard formulas for Operations and Maintenance, Administration, Material Handling, and other labor. For all other NEI categories, the NEIs recorded did not require a formula because respondents stated NEI values outright. The table also shows the number of measures for which each formula was used.

Table 3-7 shows that Operation and Maintenance costs are clearly the most widely referenced NEI category, while Table 3-8 displays all of the other formulas used to calculate the NEIs by category. Below are key highlights:

- Internal labor makes up the majority of calculations. Below is a brief description of the most common internal labor formulas:

  *(Hours per year due to Old Equipment - Hours per year due to New Equipment)*Loaded wage per hour.*

The hours spent per year due to the old equipment minus the hours spent per new equipment yields the hours saved due to the new energy efficient equipment. Thus, this formula calculates the hours saved multiplied by the loaded wage to yield the NEI for internal labor.

Hours per year due to Old Equipment Loaded wage per hour*

There were many cases when installing the new equipment meant that the customer was now spending zero hours on internal labor due to the new equipment. Therefore the cost was simply estimated based on the elimination of the hours spent on the old equipment.

- External labor frequently involved an outside contractor who would provide a particular service a number of times over year. With the new equipment, it was common that there were fewer external costs throughout the year. Similar to internal labor, there were many cases when installing the new equipment meant that the customer was now spending zero hours on external labor due to the new equipment. Therefore the cost was simply estimated based on the elimination of the hours spent on the old equipment.
- Parts and Supplies NEIs frequently referred to changes in the number of parts purchased resulting from the new equipment.
- There were fewer instances in which training occurred due to the new equipment. When a customer did incur a cost due to training, the cost reflected the cost associated with time spent away from their job as well as the cost of the training itself.

Table 3-7 Formulas Used to Calculate Overall NEIs for Operations and Maintenance NEIs

NEI Category	Cost/Revenue Center	Formula	Measures using formula	Percent
Operation and Maintenance	Internal Labor	(Hours per year due to Old Equipment - Hours per year due to New Equipment)*Unloaded wage per hour*Loaded factor	21	6%
		(Hours per year due to Old Equipment - Hours per year due to New Equipment)*Loaded wage per hour	153	44%
		(Hours per year due to Old Equipment - Hours per year due to New Equipment)* Times per year*Loaded wage per hour	11	3%
		(Hours per year due to Old Equipment - Hours per year due to New Equipment)* Times per year*Unloaded wage per hour*Loaded factor	1	0%
		Hours per year due to New Equipment*Loaded wage per hour	13	4%
		Hours per year due to New Equipment* Unloaded wage per hour*Loaded Factor	2	1%
		Hours per year due to Old Equipment*Loaded wage per hour	50	14%
		Hours per year due to Old Equipment * Times per year * Loaded wage per hour	7	2%
		Hours per year due to Old Equipment * Times per year * Unloaded wage per hour*Loaded Factor	6	2%
		Hours per year due to Old Equipment * Unloaded wage per hour*Loaded Factor	3	1%
		Don't Know	1	0%
		No Calculation Required- Value stated upfront	79	23%
		Operation and Maintenance Internal Labor Total	**347**	**100%**
	External Labor	(Hours per year due to Old Equipment - Hours per year due to New Equipment)* Cost per hour	24	4%
		Cost per hour * Hours per year	26	4%
		Cost per hour * Times per year	11	2%
		Hours per year * Labor Costs	1	0%
		Hours per year*Cost per hour * Times per year	17	3%
		Labor costs * Times per year	38	6%
		Times per year * Cost per hour * Labor costs	1	0%
		No Calculation Required- Value stated upfront	550	82%
		Operation and Maintenance External Labor Total	**668**	**100%**
	Parts and Supplies	Number of parts * Cost of Parts	89	81%
		Cost of parts * Number of parts * Times per year	1	1%
		Hours * Costs of Parts	1	1%
		Times per year * Cost of parts	19	17%
		Operation and Maintenance Parts and Supplies Total	**110**	**100%**
	Training	Hours * Labor Costs	20	91%
		hours * Times per year	1	5%
		No Calculation Required- Value stated upfront	1	5%
		Operation and Maintenance Training Total	**22**	**100%**
	Other	No Calculation Required- Value stated upfront	6	100%
		Operation and Maintenance Other Total	**6**	**100%**

Table 3-8 Formulas Used to Calculate Overall NEIs for All other NEIs

NEI Category	Cost/Revenue Center	Formula	Measures using formula	Percent
Administration	Internal Labor	(Hours per year due to Old Equipment - Hours per year due to New Equipment)*Loaded wage per hour	49	44%
		(Hours per year due to Old Equipment - Hours per year due to New Equipment)*Unloaded wage per hour*Loaded factor	10	9%
		No Calculation Required- Value stated upfront	53	47%
		Administration Internal Labor Total	112	100%
	External Labor	Hours*Labor Costs	2	100%
		Administration External Labor Total	**2**	**100%**
Material Handling	Internal Labor	Number of hours* Loaded wage per hour	4	9%
		Number of hours*Unloaded wage per hour* Loaded factor	1	2%
		No Calculation Required- Value stated upfront	38	88%
		Material Handling Internal Labor Total	**43**	**100%**
	External Labor	No Calculation Required- Value stated upfront	4	100%
		Material Handling External Labor Total	**4**	**100%**
Other Labor	Internal Labor	(Hours per year Old Equipment- Hours per year New Equipment)*Loaded wage per hour	7	70%
		(Hours per year due to Old Equipment - Hours per year due to New Equipment)*Unloaded wage per hour*Loaded factor	1	10%
		Times per year*Unloaded wage per hour* Loaded factor	1	10%
		No Calculation Required- Value stated upfront	1	10%
		Other Labor Internal Labor Total	**10**	**100%**

In addition, the evaluation team used information provided by respondents to estimate quantities of fuel and water saved. For fuel savings, respondents often did not know the quantities saved, but provided the cost associated with the fuel savings. Analysts used the average price of the respective fuel resources published by the EIA in order to estimate the quantity of fuel saved.

Table 3-9 Formulas Used to Calculate NEIs by Fuel Type

Fuel Type	Unit	Price
Natural Gas	Therm	$.86/therm[1]
No.2 Distillate	Gallon	$2.695/gallon[2]
No 4 Fuel Oil	Gallon	$2.57/gallon[3]
Propane	Gallon	$2.480/gallon[4]
Wood	Cord	$200.00/cord[5]
Kerosene	Gallon	$3.671/gallon[6]

[1] EIA.GOV, http://205.254.135.7/dnav/ng/ng_pri_sum_dcu_nus_a.htm
[2] EIA.GOV, http://www.eia.gov/dnav/pet/pet_sum_mkt_a_EPD2_PTA_dpgal_a.htm
[3] Environmental Defense Fund, http://www.edf.org/sites/default/files/10071_EDF_BottomBarrel_Ch3.pdf
[4] EIA.GOV, http://www.eia.gov/dnav/pet/pet_sum_mkt_a_EPLLPA_PTA_dpgal_a.htm
[5] EIA.GOV, www.eia.gov/neic/experts/heatcalc.xls
[6] EIA.GOV, http://www.eia.gov/dnav/pet/pet_sum_mkt_a_EPPK_PTG_dpgal_a.htm

For water savings, respondents frequently indicated savings, but could not estimate the amount of water saved. While some respondents did provide a specific monetary cost associated with the water savings, many did not know the cost of water saved. For respondents who knew they saved water, but could not provide additional information, the evaluation team based water savings estimates on the Massachusetts TRM using values of gallons per measure as used in the TRM to estimate energy savings.[19]

4. Identify incomplete and incorrectly calculated NEIs

Assigning interview responses to the standard formulas enabled data analysts to identify incomplete, incorrect, and illogical responses. Analysts first identified responses for which the respondent did not provide all the necessary information for computing NEIs. These responses were coded as incomplete and handled according to the procedures described in the section on “impute missing values” below.

Interviewers frequently constructed preliminary NEI formulas and computed rough NEI estimates based on information provided during the interviews. Upon reviewing these data, the data analysts occasionally needed to recalculate NEIs. Some respondents included revenue increases resulting from additional production and sales, but failed to estimate the increase in costs associated with the additional sales, such as raw material costs for industrial participants or re-stocking costs for retailers.

[19] http://www.ma-eeac.org/docs/MA%20TRM_2011%20PLAN%20VERSION.PDF

During the QC process, the Evaluation Team realized that a number of NEIs resulted from measures that were either replaced on failure of the existing measure or replacing a functioning measure that was scheduled to be replaced immediately. The Team determined that the portion of the NEI associated with these measure's "newness" was not applicable to the program because the participant would have incurred that benefit or cost without the program. Reviewing the formula used to compute attribution in the 2010 FR/SO study revealed that the attribution rate alone did not account for this distinction. Therefore, the following adjustment to the NEI estimates was required.

- DNV KEMA identified measures with 100% scores to the timing component free ridership. These measures were determined to be set for immediate replacement either through equipment failure, or some other reason.

- Then, we identified the percent of the NEI that respondents reported was due to the measure being energy efficient in the NEI survey.

- We multiplied the estimated NEI for each measure by the percent due to it being energy efficient to estimate the amount of the NEI that did not result from the measure's newness.

5. Verify NEIs applied to all relevant measures

Interviewers frequently conducted interviews spanning multiple measures and addresses. In these interviews, respondents were asked to provide NEI estimates for the typical or average impact across all relevant locations. They were also asked to identify the measures and locations to which each set of NEI values applied. Some respondents could not provide average responses and instead indicated the NEI applied to all locations. In these cases, the data analyst divided NEI responses by the number of relevant measures. In other cases, respondents could not provide a full accounting of all locations where measures were installed, so interviewers collected information about a typical site and applied that value for all of the respondent's relevant sites.

6. Identify double counting of NEIs

Data analysts examined NEIs reported for each cost and revenue center within each NEI category. By reviewing the sources of each reported NEI, their descriptions, and metrics, analysts ensured that a single NEI was not reported for multiple NEI categories. For example, analysts verified that reductions to internal labor reported under O&M was not also recorded under internal labor for Other Labor or Administration.

7. Eliminate invalid NEIs

Occasionally, respondents reported NEIs that should not be included in the analysis. In some instances, we flagged responses as invalid because they were impacts accounted for in the PA benefit-cost models as other energy or resource related impacts. For example, one respondent reported high "other revenue" resulting from clean energy credits which was separately accounted for in the PAs benefit-cost models.

8. Coordinate with interviewers to verify assumptions or schedule callbacks

When necessary, a few respondents were called back to either collect missing data or to verify the applicability of NEI estimates to additional locations. Data analysts first coordinated with the interviewers to determine whether the interviewer knew the necessary information, or needed to make a follow up phone call to capture the data.

9. Impute missing values

Approximately 40 respondents provided incomplete information for one or more of the NEIs for a measure. Imputing values for partial responses provided for reduced standard errors without biasing the results. DNV KEMA used published data to impute values for the missing variables, which included the ratio of loaded to unloaded wages, waste disposal costs, and costs of production. For less than 10 missing values, analysts used the mean value by end use from the interview responses to impute the missing values, each of these are discussed below. For a number of the missing values there were no published data. For example, there were no data reporting the reduction in the average number of parts replaced due to the new EE measure. Further for some missing values, identifying the correct published values would require many assumptions that were themselves difficult determine. For those missing values, we imputed the average from survey responses. Appendix G presents sensitivity analysis of the NEI results with and without imputed values to ensure that magnitude of NEI estimates was dependent upon values imputed from the overall set of survey responses.

Loaded to unloaded wage factors – The most common metric missing from the interview response was a measure of employee benefits, or the loaded wage. As seen in Table 3-7 and Table 3-8, many respondents provided the “unloaded wage” for NEI computations, but were not able to provide the fully loaded wage. In cases where only the unloaded wage was provided, analysts estimated the fully loaded wage based on information provided by the Bureau of Labor Statistics, which describes employer costs per hour worked for employee compensation and costs as a percent of total compensation. Employee wages without benefits make up 69.4% of total compensation on average. The average is based on all workers in the non-farm and non-federal sectors.

Waste disposal costs – One respondent reported decreased disposal costs for lighting measures, but did not provide a unit cost of disposal.[20] DNV KEMA assumed an average waste disposal cost of $0.60/lb. Based on information published by the US EPA regarding lighting waste, disposal costs vary between $1.50/lb and $0.60/lb. Therefore, our assumed value of $0.60/lb provides for a conservative estimate of NEI resulting from decreased waste disposal. (Note: if the PAs offer waste disposal as a service of the programs they should not apply this NEI.)

Production cost changes – Five respondent provided NEI estimates for increased revenue resulting from production increases, but provided no information concerning the corresponding increase in costs. For each of these cases, DNV KEMA assumed an average profit margin for the corresponding industry based on published sources to impute the costs.[21] [22] [23] [24] [25]

[20] http://www.dep.state.fl.us/waste/quick_topics/publications/shw/mercury/wastedi.pdf
[21] http://biz.yahoo.com/ic/322.htmlhttp://biz.yahoo.com/p/sum_qpmd.html
[22] ttp://biz.yahoo.com/ic/322.html
[23] http://biz.yahoo.com/ic/712.html, http://biz.yahoo.com/ic/715.html
[24] http://biz.yahoo.com/ic/627.html
[25] http://biz.yahoo.com/ic/322.html

Remaining intermediate missing values – For each of the missing intermediate values shown in Table 3-10, DNV KEMA used the average value by reporting category from the completed interviews, For HCAC and building envelope, the average values do cross electric and gas, but this impacted less than 10 cases. The n's shown represent the number of measures included in the average.

Missing cost details of information – There were 11 measures for which the respondents reported a definite reduction in costs in a category, but provided no other information. Five of these were for "O&M costs," two were "Administrative costs," one was "material handling," and two were "other costs." In each of these cases, analysts first estimated the average NEI per savings ratio for the corresponding reporting category in the study across all completed measures that also had a decrease in costs. Analysts then multiplied this ratio by the reported savings for the measure to impute a NEI estimate for the measure

- Operations and Maintenance had the most missing values for the NEI calculations.

  Internal Labor, hours per year: In some cases, the customer could not estimate the change in the number of hours for an employee due to the new energy efficient equipment. To complete the NEI calculation, DNV KEMA used an average change in hours and multiplied that value by the loaded wage for that employee.

  Internal Labor, loaded wage per hour: The loaded wage per hour was the most common missing value for Operations and Maintenance. In some cases, the customer provided the change in hours due to the new equipment, but could not provide the hourly wage. DNV KEMA used an average value for hourly wage to calculate the NEI.

  Parts and Supplies: For parts and supplies, DNV KEMA generated an average for Costs of parts, Number of parts, Labor Costs, and Cost per hour. For this cost/revenue center, customer could provide the cost of parts, but could not estimate the change in the number of parts purchased since the installation of the new equipment. Other customers could provide the number of parts, but could estimate the cost of those parts. Additionally, some customers knew that there was a change in the purchasing of parts and supplies but could not estimate the yearly costs (titled as Labor Costs) due to that change in purchasing of parts and supplies. Therefore, DNV KEMA created the average value across the complete survey responses for each input in order to generate the NEI.

- Admin, Internal Labor: Like Operation and Maintenance, it was necessary to generate averages for the change in hours due to the new energy efficient equipment. The change in hours was multiplied by the internal labor employee loaded wage per hour. For admin, DNV KEMA generated an average for only internal labor. There was no need to create an average for any other cost/revenue center.

- For Other Labor, Product Spoilage, and Waste Disposal, the data was incomplete but respondents often would indicate there was a change in each category, but could not estimate the dollar value of the NEI. DNV KEMA imputed the average for the dollar value of the NEI by reporting category across respondents who provided a response.

Table 3-10 Average Value of Variables for NEI Calculation

Business Function	Formula	Variable	Building Envelope n=52	Comprehensive n=26	Compressed Air n=12	HVAC n=138	Lighting n=252	Motors and Drives n=92	Other n=10	Process n=11	Refrigeration n=120	Water Heater n=70
Operation and Maintenance	Internal Labor	Hours per year spent due to New Equipment	0	0	100	44	34	127	0	2,400	28	4
		Hours per year spent due to Old Equipment	147	10	28	136	175	145	157	939	32	16
		Loaded wage per hour	$25	$22	$46	$37	$32	$36	$25	$34	$34	$38
		Days per year	0	300	5	202	200	185	0	0	0	0
		Dollar value of NEI	$3,734	$4	$7,831	$4,017	$4,886	$2,967	$3,890	$8,690	$2,762	$1,018
	External Labor	Labor Costs	$2,357	$0	$3,500	$4,261	$13,608	$2,747	$1,000	$100	$400	$2,665
		Cost per hour	$0	$0	$0	$190	$79	$96	$0	$0	$86	$306
	Parts and Supplies	Cost of parts	$559	0	8,000	1,512	1,165	1,277	0	0	1,331	188
		Number of parts	86	0	2	6	223	30	0	0	13	1
		Dollar value of NEI	$5,454	$0	$12,964	$1,749	$25,484	$1,704	$2,100	$327,807	$16,300	$423
Administration	Internal Labor	Hours per year spent due to New Equipment	0	0	0	1	1	0	0	0	0	0
		Hours per year spent due to Old Equipment	54	0	3	31	38	8	0	0	1	2
		Loaded wage per year	$45	$0	$30	$2,257	$30	$21	$0	$0	$10	$31
Other Labor	N/A	Dollar value of NEI	$0	$0	$19,800	$16,440	$1,851	$50	$27,300	$24,000	$0	$456
Product Spoilage	N/A	Dollar value of NEI	$161	$0	$3,100	$1,918	$0	$20,000	$0	$20,000	$109,500	$0

10. Review and treat extreme values

To identify potential outliers, DNV KEMA conducted an additional QC review of NEIs that met any of the following criteria:

- Measures with negative overall NEI values;
- Measures with an NEI greater than $15,000. In addition, measures with greater than $50,000 in overall NEIs also passed through a final verification by a team of senior KEMA analysts.
- Measures with NEIs that exceeded five times the non-zero mean NEI within the same reporting group and savings type (kWh or therm).
- Measures that had NEI with a standard deviation two times the standard deviation of the measures with non-zero NEIs of the same end use.

The initial QC of the interview data revealed roughly 50 extreme values. However, most of the values initially thought to be outliers were reduced or set to zero upon further review of the survey responses. Because the interviewer's primary function was to probe for and record NEI information, they did not attempt to evaluate whether all of the data provided would pass the rigorous QC process. Within the QC process, we identified extreme values and re-assessed the assumptions used to estimate them. In a number of cases the values were deemed to be either double counted or reporting values the team decided should not be reflected in NEIs.

Ultimately, DNV KEMA found only two measures that were considered outliers. One had a substantial increase in production due to the new measure. The other had a cost savings in insurance payments due to a safety improvement from the installed measure. Each had NEI dollar values greater than $100,000 and reasons for the NEIs that were not seen in other surveyed sites. In order to keep these measures from biasing the results, but at the same time respect the fact that the unusual does happen, we made sure that each measure represented only itself in the study by assigning it a weight of one. Information provided by the interview allowed us to conclude that, while valid responses, these cases should not receive the sample weight associated with the stratum. By unit weighting extreme value, we are assuming that the case is not representative of other cases within the pre-defined stratum and represents itself. We are including it in the average, but not saying it is representative of other cases.

11. Compute total NEIs

The last step in the data coding and quality control phase was to calculate total NEIs for the measure by summing across the different NEI categories at the individual measure level.

Extrapolation of results and gross NEI/kWh and NEI/therm

DNV KEMA used the statistical procedure of ratio estimation to develop estimates of NEI per kWh or per therm, for electric and gas measures, respectively. Once the individual measure level NEIs were calculated, the final step was to expand the sample results to the population of measures. This was accomplished by calculating the ratio of NEI (in dollars) to reported savings for the sample. The ratios are also referred to in this analysis as adjustment factors.

The evaluation team used ratio estimates to extrapolate measure level NEIs to the population of measures. The calculation of the NEI adjustment factor used appropriate weights corresponding to the sampling rate. The adjustment factor was calculated as a ratio estimator over the sample of interest (Cochran, 1977, p.165). The formulas for these factors are given below.

The NEI rate R_I was calculated using:

$$R_I = \frac{\sum_{j \varepsilon A} G_{Ij} w_{Aj}}{\sum_{j \varepsilon A} G_{Tj} w_{Aj}}.$$

Where:

G_{Tj} = tracking estimate of gross savings for measure *j*

G_{Ij} = evaluation estimate of gross non energy impacts for measure *j*

w_{Aj} = weighting factor for measure j used to expand the sample to the full population[26]

The ratio estimator was calculated using a SAS® macro for ratio estimation by domains. The procedure also returned the standard error of the estimate. The standard error was calculated using two methods.

The first method recognized the sample as drawn from a finite population: the measures completed within the analysis period with associated energy impacts in the program-tracking database. This calculation used the Finite Population Correction (FPC) factor.

> *Finite Population Correction* – This factor is a reduction to the calculated variance that accounts for the fact that a relatively large fraction of the population of interest has been observed directly and is not subject to uncertainty. It is appropriate to apply precision statistics, such as confidence intervals, based on the standard error calculated in this manner when quantifying the results of the program during the study period only.

The second calculation treated the population of interest as essentially infinite. Thus, the population of measures completed to date and the sample were assumed to have a virtually infinite number of combinations of measures that could have been completed under the program. In this case, the FPC was not included. It is appropriate to apply standard errors calculated in this manner when applying the verification factors developed from this study to tracked savings from other years to estimate NEIs in those years. Confidence intervals reported in this document do not include the FPC.

[26] Because the sample for the prescriptive studies were pulled from the measures completed in the 2011 FR/SO studies, the weighting factor for the prescriptive studies consists of two parts multiplied together: the selection probability for the measure in the 2011 FR/SO study and the selection probability from this study.

3.4.2 Analysis of Attribution – Net Non-energy Impacts

Because the analysis followed the same group of respondents through from the 2010 participant FR/SO study to this NEI study, the evaluation team was able to track the attribution rates of people who did and did not report NEIs. This enabled us to examine potential differences in attribution rates for participants who realize NEIs and those who do not. Specifically, we explore whether it is appropriate to apply the same attribution rate used to estimate net savings, when estimating net NEIs.

Currently, the PAs compute NEIs attributable to program activities by multiplying an estimate of NEI per unit of gross savings (e.g. per kWh) by gross savings for a measure or measure group. They multiply the resulting measure NEIs by the measure's attribution rate to calculate net NEI for the measure. This approach assumes that participants who experience NEIs have the same free ridership rate as those who do not. If free ridership rates are higher among participants who experience non-energy benefits, then the overall free ridership rate is not the appropriate value to use for non-energy impacts.

DNV KEMA's analysis applied the attribution rate from the 2010 participant FR/SO study for each respondent to the gross NEIs estimated in the present study. This provided a revised estimate of net NEIs specific to each respondent. We then calculated the average net NEI by reporting category, and compared it to the net NEIs using the traditional approach, and compared the two approaches. The evaluation team further explored differences in attribution rates and net NEIs for individuals who did and did not expect to receive NEIs prior to participation. Finally, we examined the impact of program marketing on NEI expectations and program attribution.

3.4.3 Spillover

The interview response data were used to identify the incidence of like and unlike spillover at the respondent level. "Like" spillover is identified as an energy efficient measure that was installed without an incentive that was exactly the same type of measure for which the customer received program support. "Unlike" spillover is an energy efficient measure that was installed by the customer that was neither incentivized nor the same as past program supported measures. In addition to the characterization of spillover, the analysis provides the percent of respondents who stated the program influenced their decision to install the like and unlike spillover measures. DNV KEMA's approach for estimating the incidence of like and unlike spillover was as follows:

1. We compiled the responses to all spillover questions from each respondent. Because respondents frequently reported on measures across multiple locations, we grouped spillover information by respondent, and considered reported spillover data across locations.
2. We identified whether the respondents reported having received an incentive for the noted spillover measure. Measures that were noted to have received an incentive were eliminated because they do not qualify as spillover.
3. We identified all measures for each respondent across all addresses reported by the PAs program tracking records. Interviews frequently spanned multiple measures and locations.
4. We compared the spillover measure descriptions and the program supported measures corresponding to the various locations to determine if the reported measure was "like" or "unlike" the measures listed in the tracking records for each respondent.

Many of the respondents reported having received incentives for the measures reported as spillover; therefore, these measures were eliminated from the analysis. The analysis also revealed that many measures reported as spillover by multi-building facilities, chains, or franchises participants installed the measures at locations other than the locations noted in the PA tracking records. Should a quantification of the kWh or therm savings be associated with these spillover measures, DNV KEMA suggests that the savings be divided between the number of buildings for which the owner received program support.

Further, it was also found that for many measures, there was not sufficient information to estimate savings or even classify the savings as high or low impacts. There were several reasons for this finding. First, the primary focus of this study was the more detailed NEI information and the individual being interviewed was asked to focus on all measures installed across their organization, rather than at a specific location. Secondly, the target respondents were those who were most knowledgeable of the specific business impacts of installed energy efficiency measures. While capable of providing the impacts on business operations, this person often did not know the specific engineering or purchasing details of the measures installed. Lastly, it is believed that respondent fatigue became a factor and limited the accuracy and amount of detail the respondents provided when answering the spillover questions. After answering the complex set of NEI questions, respondents provided brief, non-descript answers or referred the question to another department or person in their organization.

4. RESULTS

In this section, we present the results of NEI estimates, analysis of the attribution of NEIs (net NEI), and spillover. First, we present the gross NEI estimates for prescriptive and custom projects. Next, we present results that follow the model development process as we identify the survey and other data collection results used as model inputs.

4.1 NON-ENERGY IMPACTS

DNV KEMA captured NEI information for 789 prescriptive and custom electric and gas measures. Positive NEIs or non-energy impact benefits were realized for 58% of measures, while 3% of measures resulted in negative NEIs, non-energy impact costs. An additional 40% of measures reported no positive or negative NEIs. Table 4-1 presents a summary of the number of measures reporting NEIs of different values across all measure and fuel types.

Table 4-1
Number of measures reporting NEIs:
by Size of NEI

NEI Value	Number of measures	Percent of measures
Negative	22	3%
Zero	315	40%
Greater than Zero to $1,000	235	30%
Greater than $1,000 to $5,000	119	15%
Greater than $5,000 to $10,000	44	6%
Greater than $10,000 to $15,000	15	2%
Greater than $15,000 to $50,000	29	4%
Greater than $50,000 to $100,000	8	1%
Greater than $100,000	2	0%
Total	789	

Table 4-2 and Table 4-3 present some of the key anecdotal findings. Table 4-2 and 4-3 present information pertaining to the electric measures, while the data presented in Table 4-4 pertains to gas measure NEI interviews. This information may be useful for future marketing activities.

Table 4-2 Sources of Non-Energy Impact – Electric Measures

NEI Category	NEI Description	Impact Description	Prescriptive	Custom
Annual operations and maintenance costs	1. Avoided light bulb and ballast changes	LED lighting decreases bulb changes and staff time to identify burnt out bulbs.	✓	✓
		Occupancy sensors eliminates twice daily building checks to turn lights on and off.	✓	✓
	2. Avoided routine maintenance and repairs	New compressor requires less frequent oil changes.	✓	
		VFDs decreases frequency of system inspections needed.	✓	
	3. Avoided electrician/service visits	Decreases external service contract by 30% annually due to fewer bulb and ballast changes.	✓	✓
		Saves 20 hours/year contractor labor (at $90/hour) on decreased bulb and ballast changes.	✓	✓
		Saves 9 annual contractor visits; customer able to diagnose problems using Web-based system.	✓	✓
	4. Avoided system monitoring/equipment checks (automatic sensor monitoring)	Lighting occupancy sensors eliminates staff twice daily building tours to turn lights on and off.	✓	✓
	5. Avoided parts (e.g. bulbs, filters, etc.)	Less frequent lamp changes decreases purchase of light bulbs, ballast and gloves (due to heat of lamps)	✓	✓
Administration costs	1. Avoided electrician/service invoice processing	Saved 2 hours/month processing external contractor invoices.	✓	✓
	2. Avoided service or parts/supplies procurement	Fewer bulb changes saves 4 hours/year ordering light bulbs, ballasts and gloves.	✓	✓
	3. Avoided external contractor coordination	Saves one hour administrative staff time coordination for each avoided contractor visit.	✓	✓
	4. Avoided tenant/customer equipment complaints	Building control system automates temperature setting and saves 6 tenant calls per week	✓	✓
Materials handling	1. Avoided parts handling in warehouse	Eliminates one stockroom FTE at $18,000/year due to decreased light bulb changes.	✓	✓
		Saves 25 hours/year staff time on receiving and stocking equipment.	✓	✓

Table 4-3 Description of Electric Measure Non-Energy Impacts (continued)

NEI Category	NEI Description	Impact Description	Prescriptive	Custom
Materials movement	1. Fewer parts deliveries	Decreases central supply deliveries to maintenance dept staff.	✓	✓
	2. Avoided gasoline to pick up parts/supplies	Fewer trips to pick up lighting supplies saves 10 gallons of gas/year.	✓	✓
	3. Avoided vehicle maintenance (fewer parts/supplies pickups)	Saves $200/year on wear and tear of company vehicles to pick up lighting supplies.	✓	✓
Other labor	1. Avoided staff down time	New compressor breaks down less often and eliminates 20 – 30 hrs /year staff down time.	✓	
		Avoides two chiller failures/year and saves 8 hours/year staff downtime.	✓	
Water usage and wastewater	1. Avoided water pumped	VFDs installed on water pumps saves 10.5 million gallons/year per motor.	✓	
	2. Avoided water usage	Customer's water usage decreases by 250,000 gallons/yr after installing new HVAC system.	✓	✓
Product spoilage	1. Avoided product loss - manufacturing	Avoides $5,000 annual product lost due to old compressor failing mid-manufacturing process.	✓	
	2. Avoided product loss - non-manufacturing	Improved refrigeration equipment saves customer $73,000 in avoided food spoilage annually across 10 stores.	✓	✓
Waste disposal	1. Avoided waste disposal	Customer disposes of six fewer bulbs/month and saves $3.50 per lamp or $252/annually.	✓	✓
		Customer saves $200 annually due to decreased waste oil.	✓	✓
	2. Avoided waste disposal contract	Saves $340 per year on external lighting contract due to lower bulb & ballast waste disposal costs.	✓	✓
Fees	--	--		
Other costs	1. Avoided manufacturing downtime	Avoides 20 – 30 hrs /year staff time lost when compressor failed.	✓	
	2. Avoided accidents	Outdoor LED lighting improves visibility and decreased accidents; saves $80,000 per incident in lost productivity, medical bills, and insurance premium increases.	✓	✓
Sales	1. Improved product lighting	Quality of LED lighting allows better viewing of products and increases sales.	✓	✓
Rent revenues	1. Decrease/avoid building vacancy	Avoids rent increases and decreases risk of vacancy due to lower utility costs (from HVAC/lighting upgrades).	✓	
		Customer plans to decrease rental rates (50 cents/sq ft) to fill vacancies due to decreased electricity usage costs.	✓	
Other revenue	1. Increased property value	Installed EMS system increases property value by $500,000, based on $50,000/year in energy savings).	✓	✓
	2. Increased productivity	Better lighting improves employee productivity, and requires fewer man hours to do the same job.	✓	✓

Table 4-4 Sources of Non-Energy Impact – Gas Measures

NEI Category	NEI Description	Impact Description
Annual operations and maintenance costs	1. Avoided maintenance/repair	Improved insulation saved customer $1,500 annually on roof maintenance. New boiler saved customer 120 hours annual staff time in avoided repairs.
	2. Avoided plumber/HVAC service visits	Customer saved $4,000 per year in avoided HVAC contractor visits because new boiler requires fewer repairs.
	3. Avoided parts (e.g. thermostats, lubricating oil, filters, etc.)	Customer saved $1,400 annually in plexi glass pane window replacement parts due to building envelope measure installation. EMS system saved $500/month in pneumatic thermostats and other supplies.
	4. Avoided HVAC system monitoring/checks (sensors/monitor remotely)	Installed EMS system saves 26 hours annual staff time to monitor and adjust thermostats Customer's new EMS system saved $1,040 annually in avoided contractor labor to set and check thermostats.
Administration costs	1. Avoided invoice processing	Customer saved 24 hours/year in avoided bill payment and processing (contractor and parts/supplies)
	2. Avoided labor handling maintenance/repair	Customer saved 20 hours/year in avoided phone calls and paperwork handling maintenance and repair issues.
Materials handling	1. Avoided stockroom labor	Customer decreased stockroom labor to receive and store parts (new boiler requires fewer repairs and parts).
Materials movement	1. Avoided gasoline	New HVAC system saved customer $400/year in automobile gasoline costs due to decreased HVAC repairs and travel among multiple facilities.
Other labor	1. Avoided labor downtime	Customer saved ~$400 in avoided staff time waiting because new hot water is instantaneous.
Water usage and wastewater	1. Avoided water loss	Customer avoided wasted water from small, constant water leaks from old boilers.
Product spoilage	--	--
Waste disposal	1. Avoided waste disposal	Customer avoided disposal costs of wastewater (oil/water) drum due to new HVAC system installation. Customer saved ~$100/year in avoided mercury disposal due to new EMS system.
Fees	1. Avoided inspection fee	Custsomer avoided EPA inspection for tank water heater because installed tankless
Other costs	1. Avoided energy usage	Customer eliminated heating costs at one building (saved 1 million BTUs/hour) due to new manufacturing compressor which is water cooled and heats facility.
Sales	--	--
Rent revenues	--	--
Other revenue	1. Increased property value	Customer estimated property value rose $200,000-$500,000 due to new boiler system.

The estimates for gross NEIs per unit of energy savings are presented below. Electric results are reported by end use, while gas results are by measure category. The measures are aggregated or disaggregated to the level of reporting appropriate for the PAs. The NEI estimates were aggregated to major reporting categories that provide for the greatest degree of statistical precision.[27]

In addition to monetized NEIs, we present estimates of resource impacts, which quantify water and non-electric energy savings resulting from the installed measures.

4.1.1 Prescriptive measure results

DNV KEMA captured NEI information for 302 prescriptive electric and 98 prescriptive gas measures. For prescriptive electric measures, we exceeded the target number of completes for lighting measures. Completing a census of the remaining reporting categories provided an additional 139 measures. For prescriptive gas measures, we exhausted a census of all measures in the sample frame.

Electric Measures

Table 4-5 presents the NEI estimates for prescriptive electric measures. DNV KEMA collapsed electric end uses into four “NEI Reporting categories” to provide separate NEI estimates for lighting, motors and drives, HVAC, and all other prescriptive electric measures. This provided for statistically reliable NEI estimates across each of the reporting categories. The table shows the estimated NEI per kWh for each reporting category, as well as the 90% confidence interval for the estimate. We also show the percent of the kWh savings represented by each measure category, and the average estimated NEI using the ratio of NEI/kWh and the average savings for each reporting category.

HVAC measures, which included measures such as air conditioning, air handling units, and chillers, showed the highest estimated NEI ($0.097kWh), as well as the largest average NEI ($7,687 per measure). Lighting showed the second highest NEI, both in terms of NEI / kWh ($0.027/kWh) and average NEI ($1,636 per measure). Estimating NEIs associated with lighting measures are simpler than for other types of measures, because NEIs largely consisted of reduced time replacing bulbs and decreased disposal costs. DNV KEMA recommends using $0 for prescriptive electric measures that were not statistically significant (Motors and Drives, Refrigeration, and Other) because the data do not provide sufficient evidence to support a non-zero estimate.

Table 4-5 Gross Annual NEI per kWh – Prescriptive Electric

[27] Because some measures are not represented in the sample of NEI respondents, estimates are directly applicable to all measures.

Table 4-6 shows the correlation between prescriptive measure NEIs and their corresponding savings. We calculated the correlation for all prescriptive electric measures, including those respondents that reported no NEIs, and then for respondents excluding the zero NEIs. The results show a strong, statistically significant correlation whether or not the zero NEIs were included. This supports using NEI / kWh savings as a means of estimating total NEIs across prescriptive electric programs.

Table 4-6 Correlation NEI/kWh Savings
Prescriptive Electric

Table 4-7 presents the average contribution of each NEI category to the overall average NEIs. Some NEI categories resulted in an average positive NEI (e.g. a decrease in costs, or increase in sales). For these NEI categories, the percent contribution to the overall average NEI was positive. Other NEI categories resulted in an average negative NEI (e.g., an increase in costs, or decrease in sales). For these NEI categories, the percent contribution to the overall average NEI was a negative impact.

Table 4-7 Distribution of Annual NEIs by NEI Category – Prescriptive Electric

NEI Reporting Category	Admin	Fees	Material Handling	Material Movement	Other Costs	Other Labor	O&M	Other Revenue	Product Spoilage	Rent Revenue	Sales Revenue	Waste Disposal	Total Impacts
HVAC	8.2%*	0.00%	0.00%	0.00%	3.40%	-0.30%	69.8%*	0.00%	0.00%	18.90%	0.00%	0.00%	100.0%*
Lighting	5.0%*	0.00%	2.9%*	0.40%	0.00%	7.30%	73.7%*	0.00%	0.00%	0.00%	8.30%	2.3%*	100.0%*
Motors and Drives	0.6%*	0.00%	0.0%*	0.0%*	4.90%	0.20%	94.80%	0.00%	0.00%	0.00%	-0.50%	0.0%*	100.00%
Refrigeration	0.0%*	0.00%	0.0%*	0.0%*	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.0%*	100.00%
Other	1.00%	0.00%	0.0%*	0.0%*	0.00%	0.00%	99.00%	0.00%	0.00%	0.00%	0.00%	0.0%*	100.00%
NEI Reporting Category	**5.4%***	**0.00%**	**2.4%***	**0.40%**	**0.60%**	**6.10%**	**73.5%***	**0.00%**	**0.00%**	**2.80%**	**6.90%**	**2.0%***	**100.0%***
Significance:*													

Table 4-7 identifies the following sources for positive and negative NEIs from each of the NEI reporting categories:

- o *Lighting*

  Operations and Maintenance (73.7%): Respondents most commonly reported decreased time spent changing bulbs. They also reported decreased time spent overseeing contractors who replaced less efficient lighting more frequently. Additionally, respondents stated that the energy efficient light bulbs last longer, resulting in decreased cost of purchasing new bulbs

  Sales Revenue (8.3%): Respondents stated the new lighting enhances their retail display showroom, thereby making products more visible and attractive to buyers resulting in increased sales. Other respondents stated that better lighting in refrigerated cases allow respondents to see the products better, which increases sales.

Other Labor (7.3%): Multiple respondents stated that improved lighting has increased worker productivity by providing better working conditions.

Material handling (2.9%): Respondents reported a positive NEI for Material Handling for several reasons, all related to new lighting. Some stated that they saved time receiving and handling new lighting parts and supplies. Others stated that staff no longer had to wait 10 minutes every day for the lights to turn on. Another customer reported that staff no longer needed to move pallets of used T8 bulbs from the facility to the disposal site.

Waste Disposal (2.3%): All respondents reported that they are no longer spending as much money or time disposing of used bulbs.

- *Motors and drives*

Operation and Maintenance (94.8%): O&M accounts for 94.8% of the total motor and drives prescriptive electric impacts. Respondents stated that there is a decrease in labor time spent conducting repairs, cleaning existing parts, or purchasing new parts. Others have found that installing energy efficient motor controls has reduced labor time needed to monitor the system.

Other Costs (4.9%): Other Costs accounts for 3.3% of the total NEI. Respondents stated that the new motor and drives equipment has improved employee satisfaction and reduced the number of maintenance calls due to malfunctioning equipment. This in turn has reduced costs for the customer.

Sales Revenue (-0.5%): The decrease in Sales Revenue was caused by a VSD malfunction, causing the equipment to shut down for two hours.

- *HVAC*

Operation and Maintenance (69.8%): Respondents stated that there was a decrease in annual maintenance of the HVAC systems. They saved labor hours in overseeing contractor visits, repairs, and purchasing new parts or supplies.

Rent Revenue (18.9%): Respondents that owned rental properties found that the new energy HVAC equipment lowered monthly utility costs. The decrease in the utility costs allowed these respondents to drop monthly rental rates which were more competitively priced to retain or attract tenants. Another property owner stated that, due to the new HVAC equipment, the air temperature of the building remained at a more comfortable level, which has decreased renter turnover.

Other Labor (-0.3%): Respondents stated that, due to the energy efficient equipment, there are less equipment failures, which means there are fewer disruptions in the work day. Conversely, some respondents have stated that there is an increase in other labor due to preventative maintenance and increased time to ensure that all equipment is operating correctly.

- *Other*

Operation and Maintenance (99.0%): Overall, respondents stated that there was a decrease in time spent monitoring, repairing or overseeing contractor visits.

Table 4-8 presents average NEIs and NEI/kWh by industry sector.

- The data clearly show that the manufacturing sector experienced the highest average NEIs ($4,163 per measure; n=17). Manufacturers were most likely to experience NEIs resulting from multiple NEI categories, such as O&M, material handling, and material movement cost reductions as well as increased productivity and sales.
- The Public Order and Safety sector experienced the second highest average impacts ($3,908 per measure; n=8). This sector consists of fire departments, courthouses, police stations and other public facilities related to the preservation of order and safety. These facilities were most likely to see NEIs resulting from a decrease in operations and maintenance and across end uses such as lighting, HVAC, and refrigeration.
- Public Assembly also experienced high impacts; however, these are not significant.
- Conversely, food sales, mercantile, and food service experienced the lowest average impacts. For these industries, the NEIs were most likely found within O&M, and across end-uses such as lighting and refrigeration.

Table 4-8 NEI Estimates per Measure by Industry – Prescriptive Electric

Building Use	n	Average Annual NEI	NEI/kWh	90% CI Low	90% CI High	Stat Sig
Education	40	$ 2,634	$ 0.0631	$ 0.0106	$ 0.1156	Yes
Food Sales	60	$ 330	$ 0.0074	$ 0.0004	$ 0.0143	Yes
Food Service	4	$ 80	$ 0.0089	$ (0.0060)	$ 0.0238	No
Health Care	14	$ 2,966	$ 0.0106	$ 0.0021	$ 0.0192	Yes
Lodging	26	$ 1,001	$ 0.0178	$ 0.0022	$ 0.0333	Yes
Manufacturing	17	$ 4,163	$ 0.0269	$ 0.0023	$ 0.0515	Yes
Mercantile	24	$ 332	$ 0.0205	$ 0.0087	$ 0.0324	Yes
Office	43	$ 2,656	$ 0.0423	$ 0.0247	$ 0.0600	Yes
Public Assembly	10	$ 2,761	$ 0.1142	$ (0.0276)	$ 0.2561	No
Public Order and Safety	8	$ 3,908	$ 0.2241	$ 0.1721	$ 0.2760	Yes
Religious Worship	1	$ 105	$ 0.0053	$ 0.0053	$ 0.0053	No
Service	15	$ (3)	$ (0.0001)	$ (0.0009)	$ 0.0006	No
Warehouse and Storage	2	$ 2,030	$ 0.0154	$ (0.0322)	$ 0.0630	No
Other	17	$ 1,487	$ 0.0087	$ 0.0063	$ 0.0110	Yes
Unknown	21	$ 285	$ 0.0130	$ 0.0013	$ 0.0247	Yes
Building Use Overall	**302**	**$ 1,439**	**$ 0.0274**	**$ 0.0188**	**$ 0.0360**	**Yes**

Table 4-9 presents resource savings for prescriptive electric measures. These savings are measured in quantity of resources saved rather than dollars. The table shows that resource savings that were reported for natural gas and water savings. Because most respondents were not able to quantify resource savings, and the results were not statistically significant, DNV KEMA recommends using the average fuel and water savings provided by the TRM.

Table 4-9 Annual Resource Savings – Prescriptive Electric Measures (Natural Gas and Water Resource Savings)

		Natural Gas			Water Usage		
NEI Reporting Category	n	Average NEI (Therms)	Therms/kWh	Stat Sig	Average NEI (Gallons)	Gallons/kWh	Stat Sig
HVAC	27	964	0.0121	Yes	0	0.0000	No
Lighting	163	95	0.0016	No	0	0.0000	No
Motors and Drives	50	0	0.0000	No	167,751	1.3304	No
Refrigeration	30	0	0.0000	No	0	0.0000	No
Other	32	0	0.0000	No	0	0.0000	No
Overall	**302**	**96**	**0.0018**	**No**	**6,896**	**0.1313**	**No**

Gas Measures

Table 4-10 shows the NEI estimates for prescriptive gas measures. We collapsed prescriptive gas measure categories to provide separate NEI estimates for building envelope, HVAC, and water heater, which provides for statistically reliable NEI estimates across each of the reporting categories. The table shows the estimated NEI per therm for each reporting category, as well as the 90% confidence interval for the estimate. We also show the percent of the therm savings represented by each measure category, and show the average NEI estimated using the ratio of NEI/therm and the average savings for each reporting category.

Building envelope measures resulted in the highest NEI both in terms of NEI/therm ($3.62/therm) and average NEI ($1,551 per measure). This category included measures such as insulation and energy efficient windows and doors. Many of the NEIs for building envelope measures resulted from savings in operations and maintenance due to reduced labor in repairs and equipment replacement. HVAC measures, which include measures such as gas boilers, furnaces, and chillers, resulted in the second largest average NEI ($755 per measure) and second highest estimated NEI per therm ($1.346/therm). Most HVAC NEIs were reported as operation and maintenance savings. Through the use of energy efficient HVAC equipment, respondents stated that there was a decrease in time spent on labor and cost incurred for parts and supplies. There were fewer NEIs reported for water heater savings. Respondents noted that after the water heater was installed, there was virtually no maintenance required.

DNV KEMA recommends using $0 for prescriptive gas measures that were not statistically significant (Motors Water Heat) because the data do not provide sufficient evidence to support a non-zero estimate.

Table 4-10 Gross Annual NEI per Therm – Prescriptive Gas

NEI Reporting Category	n	Average NEI	NEI/Therm	90% CI Low	90% CI High	% of Population Therms	Stat Sig
Building Envelope	2	$ 1,551	$ 3.6151	$ 2.6418	$ 4.5885	1%	Yes
HVAC	50	$ 755	$ 1.3464	$ 0.5433	$ 2.1496	58%	Yes
Water Heater	47	$ 129	$ 0.2604	$ (0.0012)	$ 0.5221	40%	No
Overall	**99**	**$ 439**	**$ 0.8344**	**$ 0.3634**	**$ 1.3053**	**100%**	**Yes**

Table 4-11 shows the correlation between prescriptive gas measure NEIs and savings. The results show a statistically significant correlation between NEIs and savings when zero NEIs were included, but not when they were excluded. This suggests using NEI per therm savings should provide a proxy for estimating NEIs across prescriptive gas programs, but the limited sample of prescriptive gas measures (98 measures) limited our ability to capture this relationship across all measure type.

Table 4-11 Correlation NEI/therm Savings — Prescriptive Gas

Variable	Correlation: NEI:Gross Therms	P-Value
All NEIs	0.1755	0.0823
NEI not equal to zero only	0.0361	0.2860

Table 4-12 presents the average percentage contribution of each NEI category to the overall average NEIs across prescriptive gas reporting categories. Key findings include:

- *Building Envelope*

  Operations and Maintenance (100%): All respondents who installed building envelope measures stated that the equipment decreased their annual operations and maintenance costs. In general, respondents saved labor hours due to the decrease in window, roof, door, or other miscellaneous repairs.

- *HVAC*

  Operations and Maintenance (85.1%): Most respondents stated a costs savings as a result of less maintenance due to the new energy efficient equipment. Respondents also stated that labor time is reduced due to the automated thermostats.

  Rent Revenue (4.1%): Respondents that owned rental properties found that the new energy HVAC equipment lowered monthly utility costs. The decrease in the utility costs allowed these respondents to drop monthly rental rates and to become more competitive in the market. Another property owner stated that, due to the new HVAC equipment, the air temperature of the building remained at a more comfortable level, which in turn, has decreased renter turnover.

Table 4-12 Distribution of Annual NEI by NEI Category – Prescriptive Gas

NEI Reporting Category	Admin	Fees	Material Handling	Material Movement	Other Costs	Other Labor	O&M	Other Revenue	Product Spoilage	Rent Revenue	Sales Revenue	Waste Disposal	Total Impacts
Building Envelope	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.0%*	0.00%	0.00%	0.00%	0.00%	0.00%	100.0%*
HVAC	9.2%*	1.00%	0.00%	0.40%	0.00%	0.00%	85.1%*	0.00%	0.10%	4.10%	0.00%	0.00%	100.0%*
Water Heater	6.3%*	0.00%	0.00%	0.00%	0.00%	3.40%	90.20%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
NEI Reporting Category	**8.6%***	**0.80%**	**0.00%**	**0.30%**	**0.00%**	**0.50%**	**86.1%***	**0.00%**	**0.10%**	**3.40%**	**0.00%**	**0.00%**	**100.0%***
Significance=*													

Table 4-13 presents average NEIs and NEI/therm by industry sector.

- The Religious Worship sector experiences the highest significant average impacts ($1,273 per measure) and the highest significant NEI/Therm ($1.80/therm). The Religious Worship sector was most likely to experience NEIs from reduced labor costs needed to perform maintenance.
- The lodging sector experienced the second highest significant average impacts ($76 per measure) and the second highest significant NEI/Therm ($0.36/therm). Lodging was most likely to experience NEIs resulting from Operation and Maintenance as well as across all end uses.

Table 4-13 NEI Estimates by Industry – Prescriptive Gas

Building Use	n	Average Annual NEI	NEI/Therm	90% CI Low	90% CI High	Stat Sig
Education	10	$ 824	$ 3.2411	$ (1.1039)	$ 7.5860	No
Food Service	12	$ 236	$ 0.5450	$ (0.1451)	$ 1.2351	No
Health Care	1	$ -	$ 0.0000	$ 0.0000	$ 0.0000	No
Lodging	32	$ 76	$ 0.3622	$ 0.2315	$ 0.4930	Yes
Manufacturing	3	$ 396	$ 0.3530	$ (0.9599)	$ 1.6659	No
Mercantile	6	$ 496	$ 3.1565	$ (2.1894)	$ 8.5023	No
Office	5	$ 654	$ 2.8253	$ (2.8418)	$ 8.4924	No
Public Assembly	7	$ 415	$ 0.2212	$ (0.1128)	$ 0.5553	No
Public Order and Safety	2	$ 60	$ 0.4638	$ (0.4508)	$ 1.3784	No
Religious Worship	7	$ 1,273	$ 1.7961	$ 1.0524	$ 2.5399	Yes
Service	6	$ 308	$ 1.3836	$ (0.6969)	$ 3.4640	No
Other	5	$ 517	$ 0.5818	$ (0.6148)	$ 1.7784	No
Unknown	3	$ -	$ 0.0000	$ (0.0000)	$ 0.0000	No
Building Use Overall	**99**	**$ 439**	**$ 0.8344**	**$ 0.3634**	**$ 1.3053**	**Yes**

Prescriptive gas resource savings

Table 4-14 shows the resource savings for prescriptive gas measures, which were limited to water resource savings. Only savings from the water heat measure category provided statistically significant savings estimates. This reporting category contains spray valve and faucet aerator measures that are responsible for the savings.

Table 4-14 Annual Resource Savings – Prescriptive Gas Measures (Water Resource Savings)

NEI Reporting Category	n	Water Usage		
		Average NEI (Gallons)	Gallons per Therm	Stat Sig
Building Envelope	2	0	0.0000	No
HVAC	50	25,381	45.2668	No
Water Heater	47	62,942	127.1226	Yes
Prescriptive Gas Total	**99**	**44,420**	**84.3465**	**Yes**

4.1.2 Custom measure results

Electric Measures

From Table 4-15, CHP/Cogeneration measures showed the highest negative estimated NEIs (-$12,949 per measure). NEIs for cogeneration showed negative results because the energy efficient equipment required increased preventative maintenance and increase administrative costs. The Other category showed the highest average NEI ($15,937 per measure). Lighting showed the highest NEI in term of NEI/kWh ($0.056/kWh) and the second highest in average NEI ($5,686 per measure).

DNV KEMA recommends using $0 for custom electric measures that were not statistically significant (Motors and Drives) because the data do not provide sufficient evidence to support a non-zero estimate.

Table 4-15 Gross Annual NEI per kWh – Custom Electric

NEI Reporting Category	n	Average NEI	NEI/kWh	90% CI Low	90% CI High	% of Population kWh	Stat Sig
CHP/Cogen	6	$ (12,949)	$ (0.0147)	$ (0.0247)	$ (0.0047)	11%	Yes
HVAC	20	$ 5,584	$ 0.0240	$ 0.0003	$ 0.0477	28%	Yes
Lighting	89	$ 5,686	$ 0.0594	$ 0.0318	$ 0.0871	25%	Yes
Motors and Drives	42	$ 1,433	$ 0.0152	$ (0.0005)	$ 0.0309	10%	No
Refrigeration	90	$ 1,611	$ 0.0474	$ 0.0244	$ 0.0705	8%	Yes
Other	29	$ 15,937	$ 0.0562	$ 0.0038	$ 0.1087	18%	Yes
Overall	**276**	**$ 4,454**	**$ 0.0368**	**$ 0.0231**	**$ 0.0506**	**100%**	**Yes**

Table 4-16 presents the correlation between custom electric measure NEIs and their corresponding savings. The evaluation team found a statistically significant correlation between savings and NEIs. When we only considered non-zero NEIs, the correlation was greater than 50%.

Table 4-16 Correlation NEI/kWh Savings--Custom Electric

Variable	Correlation: NEI:Gross kWh	P-Value
All NEIs	0.2693	0.0000
NEI not equal to zero only	0.5659	0.0000

Table 4-17 presents the average contribution of each NEI category to the overall custom electric NEIs. Key findings from this data include:

- *CHP/Cogeneration*
- Operations and Maintenance (79.7%): Respondents reported an increase in preventative maintenance and repairs. Recall the Co-generation NEI was negative, so the positive percentage reflects a cost increase. This was largely because co-generation requires an entirely new piece of equipment.
- Administrative accounted for 20% of the overall average NEI as the new equipment requires additional back office labor to support it such as accounting and human resources.
- HVAC
- Operations and Maintenance (70.8%): The new high quality equipment required less maintenance than less efficient, and often lower quality equipment. This lead to a reduction in the O&M costs associated with new furnaces, boilers and chillers.
- Increase rent revenue for nearly 4% of the overall average as facilities are more comfortable and attractive to tenants.
- Product spoilage: Food stores and food service industries constituted a noticeable share of the sampled customers. Consequently, food spoilage was an important concern for respondents. Improved cooling systems provided for more effective ambient temperature controls, thereby reducing product spoilage.
    - HVAC – Reduced product spoilage accounted for 2.0% of average annual NEIs.
    - Motors and Drives – Reduced product spoilage accounted for nearly 30% of average annual NEIs
    - Refrigeration – Reduced product spoilage accounted for nearly 42% of average annual NEIs

Table 4-17 Distribution of Annual NEI by NEI Category – Custom Electric

NEI Reporting Category	Admin	Fees	Material Handling	Material Movement	Other Costs	Other Labor	O&M	Other Revenue	Product Spoilage	Rent Revenue	Sales Revenue	Waste Disposal	Total Impacts
CHP/Cogen	20.3%*	0.00%	0.00%	0.00%	0.00%	0.00%	79.7%*	0.00%	-0.0%*	0.00%	0.00%	-0.0%*	100.0%*
HVAC	6.10%	0.00%	0.00%	0.00%	9.60%	7.70%	70.80%	0.00%	2.00%	3.80%	0.00%	0.0%*	100.0%*
Lighting	5.2%*	0.00%	0.20%	0.40%	13.20%	0.0%*	79.7%*	0.00%	0.0%*	0.00%	0.1%*	1.2%*	100.0%*
Motors and Drives	1.40%	0.00%	0.00%	0.00%	0.00%	0.0%*	68.7%*	0.00%	29.90%	0.00%	0.00%	0.0%*	100.00%
Refrigeration	0.00%	0.00%	2.60%	0.00%	0.00%	0.0%*	55.8%*	0.00%	41.6%*	0.00%	0.00%	0.0%*	100.0%*
Other	0.00%	0.00%	0.00%	0.00%	0.00%	14.80%	-41.60%	0.00%	6.10%	0.00%	120.60%	0.10%	100.0%*
Overall	**2.40%**	**0.00%**	**0.40%**	**0.20%**	**7.60%**	**5.4%***	**40.80%**	**0.00%**	**7.8%***	**0.60%**	**34.30%**	**0.6%***	**100.0%***
Significance=*													

Table 4-18 shows that manufacturing and offices had the highest statistically significant average NEIs for custom electric measures at roughly $14,600 and $14,700, respectively. Education and Food Sales industries also showed substantial average NEIs, but at a more modest level.

Table 4-18 NEI Estimates by Industry – Custom Electric

Building Use	n	Average Annual NEI	NEI/kWh	90% CI Low	90% CI High	Stat Sig
Education	36	3,145	$ 0.0244	$ 0.0108	$ 0.0380	Yes
Food Sales	134	2,355	$ 0.0469	$ 0.0246	$ 0.0693	Yes
Food Service	1	17,331	$ 0.0933	$ 0.0933	$ 0.0933	No
Health Care	2	5,462	$ 0.0551	$ (0.0176)	$ 0.1277	No
Lodging	7	4,185	$ 0.0128	$ (0.0125)	$ 0.0380	No
Manufacturing	14	14,594	$ 0.0311	$ 0.0017	$ 0.0604	Yes
Mercantile	4	1,435	$ 0.0718	$ (0.0137)	$ 0.1572	No
Office	27	14,738	$ 0.0596	$ 0.0173	$ 0.1019	Yes
Public Assembly	2	0	$ 0.0000	$ (0.0000)	$ 0.0000	No
Public Order and Safety	4	8,805	$ 0.0663	$ 0.0005	$ 0.1321	Yes
Service	10	878	$ 0.0197	$ (0.0019)	$ 0.0413	No
Warehouse and Storage	19	524	$ 0.0257	$ 0.0079	$ 0.0434	Yes
Other	13	975	$ 0.0052	$ (0.0041)	$ 0.0145	No
Unknown	3	122	$ 0.0005	$ (0.0012)	$ 0.0021	No
Building Use Overall	**276**	**4,454**	**$ 0.0368**	**$ 0.0231**	**$ 0.0506**	**Yes**

Table 4-19 presents the savings for custom electric measures, for which survey respondents indicated resource based NEIs for propane, natural gas, and water. There were no statistically significant resource savings. However, respondents did report positive savings resulting from HVAC custom electric measures for all three resources. They also reported water savings for the “other” category.

DNV KEMA recommends using No4 heating oil NEIs for CHP/Cogeneration, lighting, and refrigeration measures only. While we did see evidence that there were resource NEIs for propane, natural gas, and water, none of these estimates were statistically significant. For these resource types, we recommend using the average resource per kWh as specified in the Massachusetts TRM.

Table 4-19 Annual Resource Savings – Custom Electric

NEI Reporting Category	n	Propane			Natural Gas			Water Usage			No4		
		Average NEI (Gallons)	Gallons /kWh	Stat Sig	Average NEI (Therms)	Therms/ kWh	Stat Sig	Average NEI (Gallons)	Gallons/kWh	Stat Sig	Average NEI (Gallons	Gallons/ kWh	Stat Sig
CHP/Cogen	6	0	0.0000	No	0	0.0000	No	0	0.0000	No	(10,324)	(0.0117)	Yes
HVAC	20	545	0.0023	No	2,848	0.0123	No	1,003,582	4.3194	No	3,954	0.0170	No
Lighting	89	0	0.0000	No	0	0.0000	No	0	0.0000	No	4,532	0.0474	Yes
Motors and Drives	42	0	0.0000	No	0	0.0000	No	5,007,857	53.2712	No	985	0.0105	Yes
Refrigeration	90	0	0.0000	No	0	0.0000	No	0	0.0000	No	899	0.0265	Yes
Other	29	0	0.0000	No	0	0.0000	No	3,707	0.0131	No	(6,630)	(0.0234)	No
Overall	**276**	**68**	**0.0006**	**No**	**355**	**0.0029**	**No**	**601,714**	**4.9769**	**No**	**1,817**	**0.0150**	**No**

Gas Measures

From Table 4-20, we see that HVAC, which includes measures such as boilers, furnaces, and gas chillers, showed the highest estimated average annual NEI ($2,798 per measure). Building Envelope, which included measure such as insulation, windows, and doors, had the second highest estimated average NEI ($922 per measure) and the highest NEI/Therm ($0.4774/Therm).

DNV KEMA recommends using $0 for custom gas measures that were not statistically significant (Water Heat and Other) because the data do not provide sufficient evidence to support a non-zero estimate.

Table 4-20 Gross Annual NEI per Therm – Custom Gas

NEI Reporting Category	n	Average NEI	NEI/Therm	90% CI Low	90% CI High	% of Population Therms	Stat Sig
Building Envelope	46	$ 922	$ 0.4774	$ 0.1258	$ 0.8290	6%	Yes
HVAC	41	$ 2,798	$ 0.2291	$ 0.1522	$ 0.3060	74%	Yes
Water Heater	23	$ 803	$ 0.1824	$ (0.4953)	$ 0.8601	8%	No
Other	2	$ 1,905	$ 0.5253	$ (5.6577)	$ 6.7083	13%	No
Overall	**112**	**$ 1,940**	**$ 0.2473**	**$ 0.1490**	**$ 0.3455**	**100%**	**Yes**

Table 4-21 shows a statistically significant correlation between savings custom gas savings and NEIs.

Table 4-21 Correlation NEI / Therm Savings -- Custom Gas

Variable	Correlation: NEI:Gross Therms	P-Value
All NEIs	0.4981	0.0000
NEI not equal to zero only	0.5601	0.0000

Table 4-22 presents the average contribution of each NEI category to the overall custom gas NEIs. Key findings from this data include:

o *Building Envelope*

Operations and Maintenance (79.1%): Respondents who installed building envelope measures stated that the equipment reduced the time spent on windows, roofs, and other repairs.

Material Movement (8.3%): One customer stated a decrease in costs on the wear and tear of company vehicles transporting goods.

o *HVAC*

Operations and Maintenance (95.8%): Most Respondents stated a staff cost savings as a result of less maintenance due to the new energy efficient equipment. Respondents also stated that labor time is reduced due to the automated thermostats.

Other Labor 0.8%): Respondents stated an increase in other labor spent on recalibrating thermostats and verifying that all equipment is functioning properly.

Table 4-22 Distribution of Annual NEI by NEI Category – Custom Gas

NEI Reporting Category	Admin	Fees	Material Handling	Material Movement	Other Costs	Other Labor	O&M	Other Revenue	Product Spoilage	Rent Revenue	Sales Revenue	Waste Disposal	Total Impacts
Building Envelope	12.10%	0.00%	0.00%	8.30%	0.00%	0.00%	79.1%*	0.00%	0.50%	0.00%	0.00%	0.00%	100.0%*
HVAC	3.0%*	0.00%	0.00%	0.00%	0.10%	0.80%	95.8%*	0.00%	0.00%	0.00%	0.00%	0.30%	100.0%*
Water Heater	57.90%	0.00%	0.00%	0.00%	0.00%	0.00%	42.10%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Overall	**7.8%***	**0.00%**	**0.00%**	**1.00%**	**0.10%**	**0.60%**	**90.2%***	**0.00%**	**0.10%**	**0.00%**	**0.00%**	**0.20%**	**100.0%***
Significance=*													

Table 4-23 presents average NEIs and NEI/therm by industry sector. The data clearly show that the Manufacturing sector experiences the highest statistically significant average impacts. Manufacturing was most likely to have NEIs resulting from categories such as O&M, material handling, and movement cost reductions as well as increased productivity and sales. These impacts were found across end uses such as building envelope, HVAC, lighting and water heating process equipment. Industry sector Public Assembly also experienced a high average impact but is not statistically significant.

Table 4-23 NEI Estimates by Industry – Custom Gas

Building Use	n	Average Annual NEI	NEI/Therm	90% CI Low	90% CI High	Stat Sig
Education	15	$ 3,125	$ 0.4786	$ 0.1141	$ 0.8431	Yes
Food Sales	1	$ -	$ 0.0000	$ 0.0000	$ 0.0000	No
Food Service	1	$ -	$ 0.0000	$ 0.0000	$ 0.0000	No
Lodging	62	$ 664	$ 0.1065	$ (0.0004)	$ 0.2133	No
Manufacturing	6	$ 4,951	$ 0.1450	$ 0.0456	$ 0.2444	Yes
Mercantile	1	$ -	$ 0.0000	$ 0.0000	$ 0.0000	No
Office	11	$ 3,920	$ 0.8545	$ 0.5173	$ 1.1917	Yes
Public Assembly	4	$ 6,280	$ 1.0628	$ (2.3208)	$ 4.4465	No
Public Order and Safety	4	$ -	$ 0.0000	$ (0.0000)	$ 0.0000	No
Religious Worship	1	$ 26	$ 0.0473	$ 0.0473	$ 0.0473	No
Warehouse and Storage	3	$ 5,437	$ 0.6125	$ (0.4969)	$ 1.7219	No
Other	3	$ -	$ 0.0000	$ (0.0000)	$ 0.0000	No
Building Use Overall	**112**	**$ 1,940**	**$ 0.2473**	**$ 0.1490**	**$ 0.3455**	**Yes**

Table 4-24 shows that respondents only reported kerosene and water resource savings for custom gas projects. However, the savings were not statistically significant. Therefore, DNV KEMA recommends using zero for custom gas resource savings. For these resource types, we recommend using the average resource per therm as specified in the Massachusetts TRM.

Table 4-24 Annual Resource Savings – Custom Gas

NEI Reporting Category	n	Kerosene			Water Usage		
		Average NEI (gallons)	Gallons/ Therm	Stat Sig	Average NEI (Gallons)	Gallons/ Therm	Stat Sig
Building Envelope	46	0	0.0000	No	0	0.0000	No
HVAC	41	643	0.0526	No	0	0.0000	No
Water Heater	23	0	0.0000	No	287,594	65.3489	No
Other	2	0	0.0000	No	0	0.0000	No
Overall	**112**	**338**	**0.0431**	**No**	**48,670**	**6.2021**	**No**

4.2 ANALYSIS OF ATTRIBUTION – NET NEIS

Currently, the PAs use a three step process to compute net NEIs for a program:

Step 1: Multiply the estimated NEI per unit of gross savings (e.g. per kWh) by gross savings for a measure or measure group to obtain gross NEIs.[28]

Step 2: Multiply the gross NEI savings estimate by the measure group specific program attribution rate to calculate net NEIs for the measure or measure group.

Step 3: Sum the measure or measure group net NEIs to calculate the net NEIs for the program.

This approach assumes that firms who experience NEIs have the same free ridership rate as those who do not (i.e. NEI values and free ridership are independent).

However, if free ridership rates are higher among participants who experience non-energy impacts, then the overall attribution rate is not the appropriate value to use for non-energy impacts. In this case, the attribution rate for NEIs would be lower than that of energy savings, reflecting the higher incidence of free ridership for NEIs. A negative correlation between program attribution and the level of NEIs experienced by participants would indicate higher free ridership rates for NEIs than for energy savings.

[28] Non-energy impact estimates are currently available for some prescriptive measures only. A number of PAs report that no NEI estimates are available for their programs.

If free ridership rates are lower among participants who experience non-energy impacts, then the overall attribution rate is also not the appropriate value to use for non-energy impacts because the attribution rate would be higher than that of energy savings, reflecting the lower incidence of free ridership for NEIs. A positive correlation between program attribution and the level of NEIs experienced by participants would indicate lower free ridership rates for NEIs than for energy savings.

DNV KEMA used program attribution rates, NEI expectation information, and the realized non-energy impacts to examine differences in attribution rates between participants who realize NEIs and those who do not report NEIs. Information regarding attribution and participant expectations of NEIs was available from the 2010 participant FR/SO study for the entire prescriptive sample and a portion of the custom measure NEI sample. To leverage the large quantity of data collected for the studies, we combined the prescriptive and custom samples into a one analysis group for each fuel type in order to explore the relationship between attribution, expectations and NEIs.

Exploring the relationship between attribution and NEIs allows us to make recommendations concerning accurate reporting of the NEIs associated with energy saving measures. Further, we examine whether the customer's expectation of NEIs and the program's influence on that expectation, appears to be a source of potential differences in the program attribution collected through the 2010 FR/SO survey,

The following sections present the results of the NEI and attribution analyses and discuss the potential relationship between expected NEIs and program marketing.

4.2.1 NEIs and Attribution

DNV KEMA used four separate analyses to explore the relationship between program the NEIs and the program attribution:

- A high level comparison of overall NEI values by attribution scores
- A visual inspection of plots of NEI to energy savings ratios and attribution scores
- An examination of the correlation statistics for NEI to energy savings ratios and attribution scores
- A comparison of approaches to estimate net NEIs

We present the results of these analyses below.

High level comparison of NEI values and attribution scores

First, measures were grouped by attribution level. We compared the average NEI and attribution values to determine if a relationship existed between the two metrics. Table 4-25 and Table 4-26 show the average NEI, and the NEI per kWh and therm for electric and gas measures respectively. The ability to identify trends was limited by the low number of cases with zero or low attribution, and high number of cases with 100 percent attribution. However the data does indicate that higher NEI to savings ratios for both electric and gas measures do correspond with low to zero attribution. The average NEIs per measure did not present a consistent trend, because NEI values tend to increase as project size increases, but attribution scores and project size were not closely related.

Table 4-25 NEIs by Attribution Level for Electric Projects

[redacted]

Table 4-26 NEIs by Attribution Level for Gas Projects

[redacted]

Visual inspection of NEI values and attribution scores

The next analysis examined the relationship between attribution and the ratio of NEIs to savings by reporting category graphically. The plots showed that variance in observed NEIs was high for all reporting categories and attribution levels. Most measures had relatively low NEI to savings ratios regardless of their attribution. While the measures with the highest NEI to savings ratios frequently also had high attribution, the majority of the measures with low NEI to savings ratios also have high attribution. The lack of diversity in attribution obscures our ability to discern relationships through visual inspection. Figure 4-1 and Figure 4-2 show the plot of NEI to savings ratios and attribution levels for electric and gas respectively.[29]

[29] In order to better display the variance among measures, two extreme data points in the electric plot and seven in the gas plot are not displayed. In the electric plot the two points (0.88, 7.25) and (1,13.48) are both lighting measures. In the gas plot five of the measures are HVAC: (0.50,65.58), (0,25.61), (0.97,19.44), (0.88,9.03), (0.88,11.02); and two are Water Heater measures: (1,35.12), (0.88,6.43).

Figure 4-1 - Plot of NEI to kWh Ratio vs. Attribution by reporting category

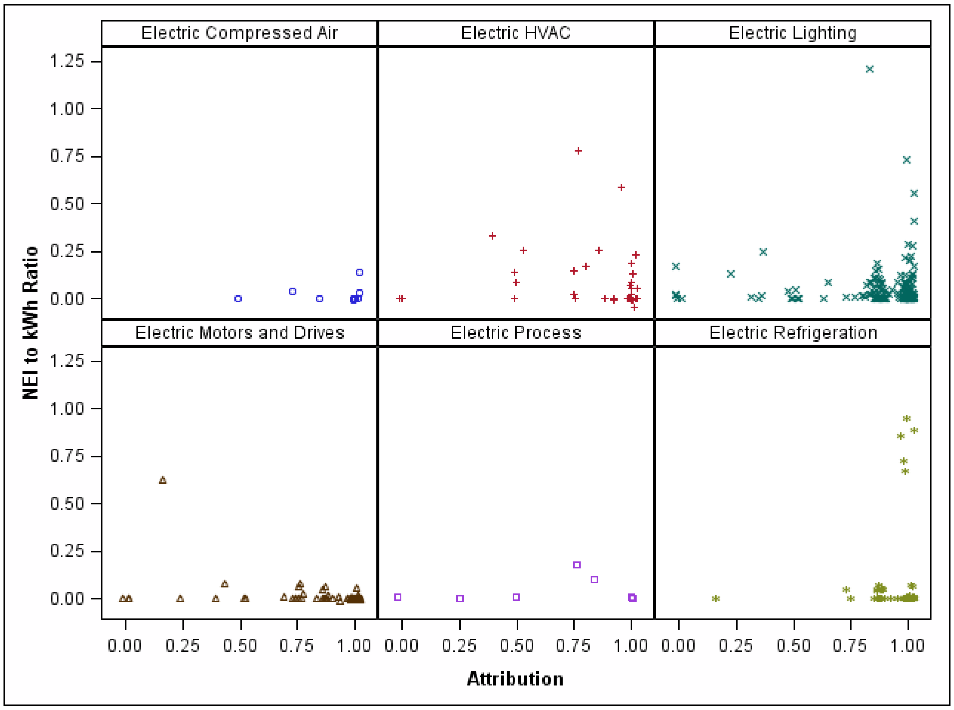
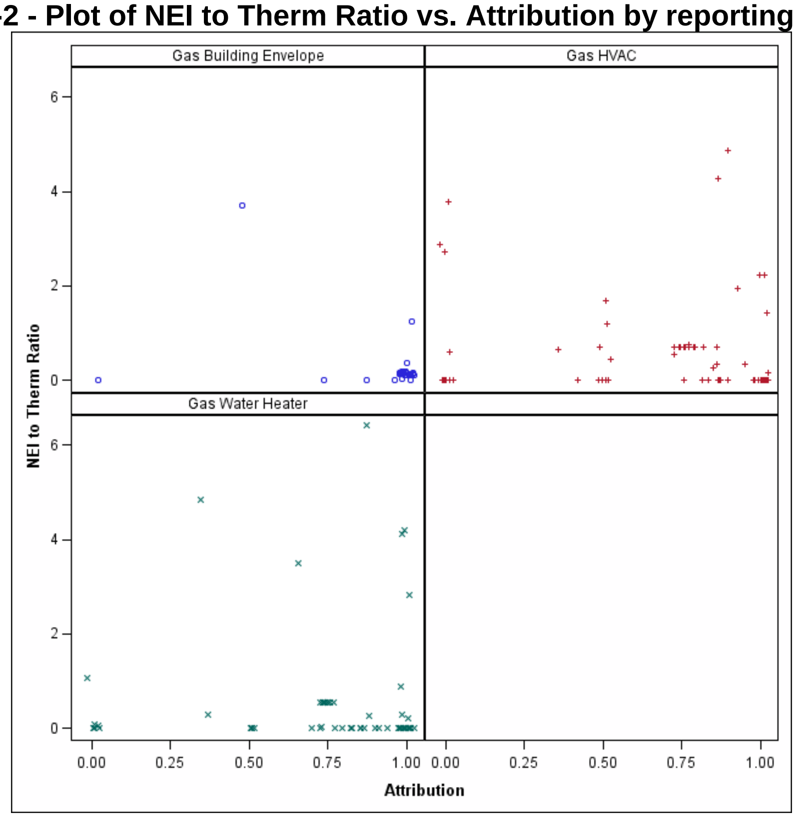


Figure 4-2 - Plot of NEI to Therm Ratio vs. Attribution by reporting category



Correlation of NEI to energy savings ratios and attribution

Third, we examined the Pearson correlation between the “NEI to savings ratio” and attribution. Table 4-27 shows the overall results for electric and gas measures by reporting category and for prescriptive and custom measures separately.

Of the nine categories for which we had enough data to calculate a correlation, five had negative correlations and four have positive correlations. This indicated that there was no systemic correlation across reporting categories. Additionally, only one of these correlations was statistically significant at the 10 percent significance level (p-value $\leq$ 0.10). This was for motors and drives, with a statistically significant negative correlation.

When we look separately by Prescriptive and Custom, the motors and drives negative correlation remained statistically significant for both, though less strongly for prescriptive. This one fairly consistent negative correlation was associated with relatively low overall NEI per unit ($0.01/kWh), so the effect of this correlation on overall NEI is limited.

Correlation for compressed air was borderline statistically significant and negative for prescriptive but for custom it was positive and not statistically significant. The small n’s for compressed air also prevented us from drawing conclusions. Custom building envelope had a positive correlation and was statistically significant.

The correlation results provided some evidence of a relationship between NEIs and attribution. Four out of the five statistically significant correlations were negative, but only five of the nine overall correlations were negative. This provided some evidence that projects with higher NEI to savings ratios were more likely to have low attribution. However, given the limited number of observations in our sample that actually had low attribution, this finding was not robust.

Table 4-27 Pearson Correlations by fuel type and reporting categories

[redacted]

Comparison of approaches to estimating net NEIs

Finally, we compared the ratio of net NEIs to gross savings using the current calculation method used by the PAs and two alternative calculation methods. By comparing different methods of calculating net NEIs were used in an effort to determine whether the current method of calculation is systemically under- or over- estimating net NEIs.

The three approaches are:

- Approach 1 is consistent with the PAs' current method of estimating net NEIs;
- Approach 2 is the most accurate method if NEIs and attribution are correlated; and
- Approach 3 provides us a way to directly compare the results from the methodology differences in approach 1 and 2.

Table 4-28 and the formulas below summarize the three approaches used in this analysis. Each approach calculated a ratio of net NEIs to Gross savings that could be applied to gross savings to estimate net NEIs. However, the approaches differed in how attribution was treated: Approaches 1 and 3 used attributions at the reporting category level, while approach 2 used individual measure level attributions. The approaches also differed in the sample of measures that were included in the analysis. Approach 1 used the full 2010 FR/SO and NEI study samples, while the sample used in approaches 2 and 3 were restricted to only measures that were included in both the 2010 FR/SO and NEI samples. Using the same sample in the latter two approaches allowed a direct comparison of how changing level at which attribution is applied changed the results.

Notation: The following terms were used in the Net NEI estimation formulas:

ATTR	=	Attribution
W	=	Weighting factor for an individual measure used to expand from the sample to the population
NEI	=	NEI study estimate of Gross NEIs
Gross	=	Tracking Estimate of Gross Savings
FULLN	=	Set of measures in the full sample used in the NEI study
FULLF	=	Set of measures in the full sample used in the 2010 FR/SO study
Intersect	=	Set of measures included in both the NEI study and 2010 FR/SO study samples
j	=	Individual measure in the Intersection sample (measures that were in both the 2011 FR/SO sample and the NEI study sample)

Approach1:

$$\frac{Net\ NEI}{Gross\ Savings} = \sum_{j=1}^{FULLF} ATTR_j W_j \times \sum_{j=1}^{FULLN} NEI_j W_j \div \sum_{j=1}^{FULLN} Gross_j W_j$$

Approach2:

$$\frac{Net\ NEI}{Gross\ Savings} = \sum_{j=1}^{Intersect} ATTR_j NEI_j W_j \div \sum_{j=1}^{Intersect} Gross_j W_j$$

Approach3:

$$\frac{Net\ NEI}{Gross\ Savings} = \sum_{j=1}^{Intersect} ATTR_j W_j \times \sum_{j=1}^{Intersect} NEI_j W_j \div \sum_{j=1}^{Intersect} Gross_j W_j$$

Table 4-28 Net NEI Estimation approaches

Approach	Label	Purpose	Aggregate or Individual Attribution	Attribution Sample	NEI per gross savings sample
1	Basic, Full samples	Simplest application of FRSO and NEI factors using all available data	Aggregate	Full FRSO	Full NEI
2	Detailed, Intersection sample	Most accurate if attribution and NEI are correlated	Individual	Intersection	Intersection
3	Basic, Intersection sample	Consistent comparison for correlation exploration	Aggregate	Intersection	Intersection

Table 4-29 and Table 4-30 show the inputs and resultant net NEI per gross savings ratios for the three calculation approaches by reporting category.

For electric measures, the overall value of the NEI to savings ratio was consistent across all three approaches. Additionally, approach 2 and 3 varied only slightly when we compare results at the reporting category level. The reporting category where the 3 approaches gave the most different results was motors and drives, it was also the one place where we saw a statistically significant overall correlation, and the difference between 2 and 3 is in the expected direction (the negative correlation between NEIs and attribution implies that approach 2 would have a lower estimate than approach 3). Approach 1 is different for motors and drives as well, indicating the effect of different samples.

For gas measures, approach 2 and 3 had only slight variance: none of the reporting categories, or the overall estimate ever had more than a five percent difference. Approach 1 had considerably different values due to the difference in populations used, but the overall value for approach 1 was also within 10 percent of the other two approaches.

Table 4-29 NEIs by Reporting Category with Alternate Estimation Methods (Electric)

[redacted]

Table 4-30 NEIs by Reporting Category with Alternate Estimation Methods (Gas)

[redacted]

Of our four analysis methods, two, the correlation analysis and the comparison of net NEI estimation methods, found some evidence of a relationship between NEIs and attribution. In both cases the strongest evidence for a relationship came for the motors and drives reporting category, which plays a small role in the program's overall NEI estimates. The high attributions from the FR/SO study may be preventing us from seeing more evidence. Eighty-five percent of the intersection sample for electric and 61% of the intersection sample for gas had attributions above 75%.

When we held the samples constant and compared the PA's current estimation method for net NEIs to an alternative approach that should result in more accurate NEIs, we found only small differences in the ratios. Our analysis of the relationship between attribution and NEIs supports continuing the PA's existing estimation method for net NEIs. Further analysis of the correlation between NEIs and attribution using different attribution scores may help shed more light on their relationship.

4.2.2 NEI Expectations and program marketing

DNV KEMA analyzed the attribution of measures for all respondents who answered the NEI expectations question in the 2010 FR/SO Study, weighted by the 2010 FR/SO study survey weights and savings. NEIs were expected for only 37% of electric measures and 33% of gas measures. Of those who expected NEIs, the program influenced this expectation in 71% of electric measures and 86 percent of gas measures. This indicates that the program is effectively marketing NEIs for close to 30 percent of installed measures overall.

The attribution of measures where the respondent expected NEIs did not vary significantly from those who did not; however, installers of both electric and gas measures who expected NEIs had slightly higher attribution when the program influenced their expectation of NEIs. This provides some evidence that effective program marketing of NEI benefits both improves attribution rates and appears to be captured using the current evaluation approach for attribution Table 4-31 indicates average attribution by fuel type, expectation of NEIs and program influence on expectation of NEIs.

Table 4-31 Average Attribution by Fuel Type and Program Influence on Expectation of NEIs

[redacted]

The analysis of the NEIs for measures in the NEI study sample, found that those who expected NEIs also reported greater NEIs both in terms of average value of NEIs and in terms of ratio of NEIs to savings, as shown in Table 4-32.

Table 4-32 NEI Values by Fuel Type Expectation of NEIs

Fuel Type	NEI Expectation	n	Average NEI	NEI/Therm	90% CI Low	90% CI High
Electric	Expected NEIs	150	$ 2,872	$ 0.04	$ 0.02	$ 0.06
	Did Not Expect NEIs	281	$ 1,154	$ 0.02	$ 0.01	$ 0.03
Gas	Expected NEIs	72	$ 1,434	$ 0.35	$ 0.20	$ 0.50
	Did Not Expect NEIs	94	$ 343	$ 0.30	$ 0.13	$ 0.46

4.3 ANALYSIS OF SPILLOVER

DNV KEMA used information provided by the in-depth interviews to provide evidence of like and unlike spillover resulting from the installed measures. As reported in Section 3.4.3, while we attempted to obtain sufficient information to estimate program-attributable spillover savings, respondents were only able to identify instances in which the program measures resulted in installation of additional equipment. In some cases, respondents identified the specific facilities at which the spillover measures were installed, while others only knew that they bought additional equipment of a certain type at one of the facilities. Few respondents provided sufficient measure descriptions to estimate spillover savings. Therefore, results of our spillover analysis were limited to the percent of respondents that reported installing measures of the same type (like spillover) and a different type (unlike spillover) at one of their facilities.

Table 4-32 presents the (unweighted) percent of interview respondents that reported installing spillover either like or unlike spillover measures at one of their reported facilities. Of the 789 measures sampled for the NEI study, 109 reported projects that KEMA determined to be likely spillover. 103 described unlike spillover projects, while only nine described like spillover projects. Of reporting categories where spillover was observed, electric building envelope and compressed air projects showed the greatest rate of spillover, with 25% of projects citing a spillover project. While HVAC, lighting and motors projects led to spillover installations in many different categories, refrigeration installations led primarily to water heating projects and respondents with spillover who installed process and compressed air projects most often installed large HVAC projects.

These results suggest that Massachusetts energy efficiency programs did result in substantial unlike spillover. However, a more targeted study is required in order to provide precise spillover estimates.

Table 4-33 Incidence of Like and Unlike Spillover by Program Measure, Spillover Measure *

Fuel Type	Program Measure	Like Spillover	Unlike Spillover by Spillover Measure and Savings Level									Overall
			Building Envelope	Compressed Air	HVAC	Lighting	Motors and Drives	Refrigeration	Water Heat	Process	Unlike Overall	
	Building Envelope n=4	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.00%	0.00%	**25.00%**	**25.00%**
	CHP/ Cogen n=6	**0.00%**	0.00%	16.70%	16.70%	0.00%	0.00%	0.00%	0.00%	0.00%	**16.70%**	**16.70%**
	Comp. Air n=12	**0.00%**	8.30%	0.00%	8.30%	0.00%	0.00%	8.30%	0.00%	0.00%	**25.00%**	**25.00%**
	HVAC n=47	**0.00%**	2.10%	0.00%	6.40%	6.40%	4.30%	4.20%	2.10%	0.00%	**19.10%**	**19.10%**
	Lighting n=252	**2.00%**	0.80%	0.80%	4.00%	6.00%	0.80%	1.60%	4.00%	0.00%	**15.10%**	**16.70%**
	Motors and Drives n=92	**2.20%**	1.10%	1.10%	2.20%	2.20%	0.00%	1.10%	4.40%	2.20%	**14.10%**	**15.20%**
	Process n=10	**0.00%**	0.00%	0.00%	10.00%	0.00%	0.00%	0.00%	0.00%	0.00%	**10.00%**	**10.00%**
	Refrig. n=120	**0.00%**	0.80%	0.00%	0.80%	0.80%	0.00%	0.80%	8.30%	0.00%	**10.00%**	**10.00%**
Electric	Other n=35	**0.00%**	2.90%	0.00%	0.00%	0.00%	0.00%	2.90%	0.00%	2.90%	**5.70%**	**5.70%**
	Building Envelope n=48	**0.00%**	4.20%	0.00%	4.20%	4.20%	0.00%	6.30%	0.00%	0.00%	**10.40%**	**10.40%**
	HVAC n=90	**1.10%**	5.60%	0.00%	4.40%	5.50%	5.50%	1.10%	0.00%	0.00%	**12.20%**	**13.30%**
Gas	Water Heater n=70	**1.40%**	0.00%	0.00%	0.00%	10.00%	1.40%	4.30%	1.40%	0.00%	**10.00%**	**10.00%**

*Results reflect the percent of un-weighted survey respondents reporting spillover

5. CONCLUSIONS

5.1 OVERVIEW

The overall goal of this study was to estimate non-energy impacts (NEIs) associated with the Massachusetts PA's C&I programs. To accomplish this goal DNV KEMA obtained self-reported non-energy impact estimates resulting from 788 electric and gas energy efficiency measures installed in 2010 through both prescriptive and custom programs. Our analysis clearly identified the presence of NEIs resulting from energy efficiency programs, providing statistically significant NEI estimates, and also significant correlations between the program savings and the level of NEIs reported.

DNV KEMA used energy industry experts to conduct in-depth interviews with program participants. We limited the sample of prescriptive measures to those measures that had a corresponding completed interview from the 2010 participant FR/SO study. For custom measures, we exhausted the pool of measures with corresponding completed interviews from the 2010 participant FR/SO study, but supplemented the sample with additional records from the population of 2010 custom measures. Using the same measures as the 2010 participant FR/SO study allowed us to link the NEI analysis to attribution estimates provided by the previous study.

DNVA KEMA obtained information regarding the cost and revenue changes resulting from the installed measures that occurred within businesses relative to 13 mutually exclusive NEI categories. Interviewers probed respondents to provide details of the resulting changes, identify the appropriate metrics for quantifying the impacts, and to obtain estimates of those metrics. This information was used to construct a series of NEI formulas that we then used to monetize impacts associated with each NEI category. The evaluation team used ratio estimation to extrapolate results to the population of measures and estimate average NEIs per unit of energy savings. We provided separate average NEI estimates for prescriptive and custom electric and gas measures aggregated into 15 separate reporting categories. In nearly all cases, we found statistically significant average NEIs per unit of energy savings.

For all prescriptive measures and the portion of custom measures also included in the 2010 participant FR/SO study, the evaluation team used the previously estimated attribution rates to examine the relationship between program-attribution and expected and realized NEIs. This provided valuable information concerning the use of independently derived attribution rates in estimating net non-energy impacts.

Finally, the evaluation team used survey responses to obtained estimates of the incidence of like and unlike spillover.

5.2 KEY FINDINGS

5.2.1 NEI Estimates

Table 5-1 summarizes the results of the NEI estimates.

Table 5-1 Summary of NEI Estimates

Electric measures	n	Average Annual NEI per Measure*	NEI/kWh	90% CI Low	90% CI High	Stat Sig
Precriptive						
HVAC	27	$ 7,687	$ 0.0966	$ 0.0544	$ 0.1389	Yes
Lighting	163	$ 1,636	$ 0.0274	$ 0.0176	$ 0.0372	Yes
Motors and Drives	50	$ 541	$ 0.0043	$ (0.0005)	$ 0.0091	No
Refrigeration	30	$ 5	$ 0.0013	$ (0.0002)	$ 0.0028	No
Other	32	$ 28	$ 0.0039	$ (0.0002)	$ 0.0079	No
Total	*302*	*$ 1,439*	*$ 0.0274*	*$ 0.0188*	*$ 0.0360*	*Yes*
Custom						
CHP/Cogen	6	$ (12,949)	$ (0.0147)	$ (0.0247)	$ (0.0047)	Yes
HVAC	20	$ 5,584	$ 0.0240	$ 0.0003	$ 0.0477	Yes
Lighting	89	$ 5,686	$ 0.0594	$ 0.0318	$ 0.0871	Yes
Motors and Drives	42	$ 1,433	$ 0.0152	$ (0.0005)	$ 0.0309	No
Refrigeration	90	$ 1,611	$ 0.0474	$ 0.0244	$ 0.0705	Yes
Other	29	$ 15,937	$ 0.0562	$ 0.0038	$ 0.1087	Yes
Total	*276*	*$ 4,454*	*$ 0.0368*	*$ 0.0231*	*$ 0.0506*	*Yes*
Gas measures	**n**	**Average Annual NEI per Measure****	**NEI/Therm**	**90% CI Low**	**90% CI High**	**Stat Sig**
Prescriptive						
Building Envelope	2	$ 1,551	$ 3.6151	$ 2.6418	$ 4.5885	Yes
HVAC	50	$ 755	$ 1.3464	$ 0.5433	$ 2.1496	Yes
Water Heater	47	$ 129	$ 0.2604	$ (0.0012)	$ 0.5221	No
Total	*99*	*$ 439*	*$ 0.8344*	*$ 0.3634*	*$ 1.3053*	*Yes*
Custom						
Building Envelope	46	$ 922	$ 0.4774	$ 0.1258	$ 0.8290	Yes
HVAC	41	$ 2,798	$ 0.2291	$ 0.1522	$ 0.3060	Yes
Water Heater	23	$ 803	$ 0.1824	$ (0.4953)	$ 0.8601	No
Other	2	$ 1,905	$ 0.5253	$ (5.6577)	$ 6.7083	No
Total	*112*	*$ 1,940*	*$ 0.2473*	*$ 0.1490*	*$ 0.3455*	*Yes*

* Equals (NEI/kWh) x (Average annual kWh)
**Equals (NEI/therm) x (Average annual therm)

Prescriptive electric measures

- DNV KEMA captured NEI information for 302 prescriptive electric measures, and provided separate statistically significant NEI estimates grouped into the following reporting categories: lighting, motors and drives, HVAC, and all other prescriptive.
- HVAC measures showed the highest estimated NEI $0.097kWh, while lighting showed the second highest NEI both in terms of NEI / kWh ($0.027/kWh) and average annual NEI ($1,636).
- We also found a strong, statistically significant correlation between savings and NEI values.

- o The resource savings that were reported by respondents was for natural gas savings. Further, only HVAC measures resulted in statistically significant annual resource savings at 964 therms.

Prescriptive gas results

- DNV KEMA captured NEI information for 98 prescriptive gas measures, and provided separate statistically significant NEI estimates for the following reporting categories: building envelope and HVAC.
- o Building Envelope measures exhibited the highest estimated NEI/therm ($3.62/therm), which also resulted in the largest average NEI ($1,551). However, while significant, this measure's NEI was estimated from only two responses. HVAC had the second highest NEI both in terms of NEI / kWh ($1.35/therm) and average NEI ($755).
- o The correlation between NEIs and savings was not statistically significant.

Custom electric measures

- o DNV KEMA captured NEI information for 276 custom electric measures, and provided separate statistically significant NEI estimates grouped into the following reporting categories: CHP/Cogeneration, HVAC, lighting, refrigeration, and other.
- o Lighting resulted in the highest NEI/kWh ($0.06/kWh) and second highest in average NEI ($5,686). NEIs for cogeneration showed negative results because the energy efficient equipment required increased preventative maintenance and increase administrative costs.
- o CPH/CoGen shows a large negative annual NEI of -$12,949 (-$0.15/kWh)
- o We also found a strong, statistically significant correlation between savings and NEI values.

Custom gas results

- DNV KEMA captured NEI information for 112 custom gas measures, and provided separate statistically significant NEI estimates for the following reporting categories: building envelope, HVAC, and other.
- o HVAC showed the highest estimated average NEI ($2,798) at $0.23/therm. Building Envelope had the second highest estimated average NEI ($922) and the highest NEI/therm ($0.76/therm).
- o We found a strong and statistically significant correlation between NEIs and savings.

Industry level results

- Manufacturing sector experienced the highest average NEIs ($4,162) for prescriptive electric measures. Manufacturers were most likely to have NEIs resulting from multiple NEI categories, such as O&M, material handling, and material movement cost reductions as well as increased productivity and sales. The Public Order and Safety sector experienced the second highest average impacts ($3,908).
- Manufacturing, and offices have the highest average NEIs for custom electric measures.

- For custom gas measures, manufacturing sector experiences the highest statistically significant average impacts. Manufacturing was most likely to see NEIs resulting from categories such as O&M, material handling, and movement cost reductions as well as increased productivity and sales. These impacts were found across end uses such as building envelope, HVAC, lighting and water heating process equipment. Industry sector Public Assembly also experienced a high average impact but is not statistically significant.

Resource savings

- DNV KEMA only found statistically significant resource savings associated with water usage for prescriptive gas measures.

5.2.2 Analysis of Attribution

- Of our four analysis methods, two, the correlation analysis and the comparison of net NEI estimation methods, found some evidence of a relationship between NEIs and attribution.
- In both cases the strongest evidence for a relationship came for the motors and drives reporting category, which plays a small role in the program's overall NEI estimates.
- The high attributions from the FR/SO study may be preventing us from seeing more evidence.
- Eighty-five percent of the intersection sample for electric and 61 percent of the intersection sample for gas had attributions above 75 percent.
- Our analysis of the relationship between attribution and NEIs supports continuing the PA's existing estimation method for net NEIs. Further analysis of the correlation between NEIs and attribution using different attribution scores may help shed more light on their relationship.
- We found evidence that effective program marketing of NEI benefits both improves attribution rates and appears to be captured using the current evaluation approach for attribution.
- Those who expected NEIs also reported greater NEIs both in terms of average value of NEIs and in terms of ratio of NEIs to savings

5.2.3 Spillover

- Massachusetts energy efficiency programs did result in substantial unlike spillover. However, a more targeted study is required in order to provide precise spillover estimates.

5.3 RECOMMENDATIONS

- National Grid and NStar should use the measure mappings provided in Appendix G to apply the appropriate NEIs to their existing programs. The remaining PAs should use the gross NEI per kWh and therm savings estimates presented in Table 1-2 to estimate NEIs, provided estimates were statistically significant. For measures corresponding to non-significant NEI estimates, the PAs should use $0.

- PAs should continue their current practice of applying the attribution rate used for estimating net energy savings to estimate net NEIs. We did not find sufficient evidence to justify altering this approach. We recommend further study of this relationship.
- DNV KEMA recommends further study of unlike spillover. Evidence provided by this report suggests high potential for unlike savings, particularly among multiple location companies. However, such a study will require more a focused engineering based approach to obtain the necessary engineering parameters needed to estimate savings. The study should also account for spillover resulting from measures installed across multiple locations.
- The PAs should continue to promote NEIs in program marketing, as their current efforts appear to be effective in driving awareness of NEIs as a source of value... Data obtained for this NEI study may provide valuable insights into key touch points for account managers promoting the programs.
- The NEI study was able to provide some evidence for resource NEIs. Capturing these effects directly in program tracking data or through on-site interviews would be best.

5.4 LIMITATIONS

- This study was primarily focused on estimating monetary NEIs associated with C&I programs. While the evaluation team did capture information pertaining to resource savings, we did not obtain sufficient data to obtain statistically reliable resource savings estimates.
- Spillover information obtained through this study was not sufficient to quantify like and unlike spillover savings associated with program measures. This is largely due to the level of complexity in the NEI interview itself, which required individuals with extensive knowledge of the business impacts associated with the installed measures. These individuals often did not have knowledge of the engineering specifications needed to estimate spillover.

  Our analysis indicated that it is important to consider technology purchases across all locations of a company when examining spillover, rather than looking at each location separately. Investment decisions in one location frequently influence subsequent decisions at other locations. Conducting spillover analysis at the facility level can result in ignoring spillover from additional locations.
- Our research approach focused primarily on identifying annual NEIs. Consequently, the results may under estimate NEIs associated with one-time costs or benefits.
- The NEI estimates provided by this study were largely influenced by O&M cost reductions. In a number of instances this change in O&M costs resulted from decreased repair costs associated with the new, high efficiency (high quality) equipment. Due to number of assumptions required to depreciate the installed equipment and amortize the cost differential, our estimates assumed that this cost differential occurs annually, over the life of the equipment. This may over estimate NEIs associated with older measures. Further

research is required to examine the appropriate treatment of NEIs associated with maintenance over time.

- NEIs may be underestimated simply due to the nature of self report surveys. Survey respondents were frequently able to identify NEIs, but we found that, for the same measure type, some did and some did not see the same NEIs across multiple respondents. For example, labor costs associated with less frequent changing of light bulbs were an NEI we would expect to find at most sites. While this was cited frequently, many sites either did not experience this impact, or it did not occur to them during the survey despite probing.
- There was an increased chance of self selection bias because much of the sample consisted of people who agreed to be interviewed twice. This was true for all of the prescriptive measures and many of the custom measures.
- The following factors may limit the applicability of NEI estimates in other jurisdictions:
  - Values were specific to Massachusetts customers. For example the general cost of labor in MA may be higher than that in a Midwestern state.
  - The mix of measures assumes C&I programs that are retrofits, which consisted of a mix of early replacement and replace on failure measures. Additional steps should be taken to address new construction.
- The following limitations apply to the applicability of this research to future years:
  - The confidence intervals reported do not correct for the 2010 population size.

  Significant program changes in terms of mix of measures, or favoring early replacement over replace on failure could make the NEI values from this study less applicable.

Appendix A. DEFINITIONS

Like spillover – Energy savings resulting from program influenced installation of energy-efficient equipment of the same type (i.e. the same measure, capacity, and efficiency level).

Non-energy benefits (or NEBs) – Positive NEIs, while negative NEIs (non-energy costs) reflect ways that energy efficiency measures result in adverse effects.

Non-electric benefits (or NEBs) – Positive NEIs, relative to electric measures only.

Non-Energy Impacts – *Non-Energy Impacts* (NEIs) include positive or negative effects attributable to energy efficiency programs apart from energy savings.

Participant benefits (or NEIs) – Monetary and non-monetary benefits (positive or negative) that directly benefit a program partner, stakeholder, trade ally, participant, or the participant's household." Examples include lower operations and maintenance costs, or increased sales or revenue."[30]

Participant spillover – Energy savings resulting from program influenced installation of energy efficiency measures that did not receive program incentives.

Resource savings – Quantities of water or fuel savings resulting from the installed measures, such as fuel oil, kerosene, propane, or natural gas savings.

Unlike spillover - reflected energy savings resulting from program influenced installation of energy-efficient equipment of a different type (i.e. different measure, capacity, or efficiency level).

Societal benefits (or NEIs) – Benefit society at large and can be provided via monetary savings to the energy provider that can be passed on to the society at large via energy price reductions or lower price increases, or benefits that directly benefit the society at large. Examples include reduced carbon emissions and lower water treatment costs.

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[30] Hall, Nick, Jeff Riggert, and Tom Talerico. TechMarket Works. *Focus on Energy Statewide Evaluation Non-Energy Benefits Cross-cutting Report: Year 1 Efforts*: *Focus on Energy*." State of Wisconsin Department of Administration Division of Energy. January 30, 2003

Appendix B. DETAILED SAMPLING PLAN: PRESCRIPTIVE MEASURES

INTRODUCTION

This memo presented the revised sampling approach for the Non-Energy Impacts (NEI) interviews associated with prescriptive measures for the Massachusetts Multi-Evaluation Tasks for Massachusetts Energy Efficiency Programs in the Special Cross-sector Studies Area. KEMA selected the prescriptive measure NEI sample from the 1,506 prescriptive projects that received surveys during the 2010 participant FR/SO, enabling us to examine potential differences in the free ridership rate on savings and NEIs. The prescriptive measure NEI study included 200 completed interviews across electric and gas projects.[31] Revisions to the sampling plan presented in this memo included the following:

- We provided a range for the expected precision of NEI estimates by varying the error ratio. The conservative estimate assumed an error ratio of 1.6, based on the 2007 custom NEBs study and presented in the original sampling plan. We also presented the expected precision assuming an error ratio of 1.0 (Optimistic Precision), which may be more representative of prescriptive measure NEIs;
- We provided alternative scenarios for sampling that expanded the scope of the prescriptive NEI study beyond 200 completed interviews. For each scenario, we provided optimistic precision estimates based on a 1.0 error ratio and also the conservative precision estimates based on an error ratio of 1.6. We also presented budgetary implications of each alternative scenario.

This memo is divided to the following sections:

- **Overview of Prescriptive Measure Sampling Approach**: Presented an overview of the general sampling approach;
- **Establishing Target Completes for Electric and Gas Measures**: Discussed separating the 200 completed interviews into those used to obtain NEI data associated with electric and gas measures;
- **Electric Measures Sample Design**: Provided details of the sampling approach for the electric measure sample;
- **Gas Measures Sample Design**: Provided details of the sampling approach for the gas measure sample; and
- **Potential Reporting Categories**: Presented our recommend approaches for grouping measures for analysis purposes.
- **Alternative Sample Design Scenarios**: Presented our alternative sample designs that expanded the scope of the prescriptive study beyond 200 interviews.

[31] "Multi-evaluation Tasks for Massachusetts Energy Efficiency Programs in the Special and Cross-sector Studies Area. Proposed 2012 Research Activities. Commercial and Industrial Non-Energy Impacts Study. Revised Work Plan." Prepared for the Massachusetts PAs. December 9, 2011.

OVERVIEW OF PRESCRIPTIVE MEASURE SAMPLING APPROACH

KEMA employed a proprietary sampling tool that used Model Based Statistical Sampling (MBSS) to produce an optimally allocated sample for stratified ratio estimation. The tool maximized precision based on the population characteristics (in this case, gross estimated savings) and the expected variance in the population on the variable being estimated. For this study, that variable was non-energy impacts. This tool is appropriate when there is a relationship between the characteristic and the variable of interest. While the 2007 TecMarket Works NEI study only found a low correlation between NEIs and energy savings, given a sufficient sample size we can accurately determine the ratio of NEIs to savings for "typical" cases[32]. The standard deviation, mean and correlation reported in the 2007 study indicated that the error ratio for the ratio of NEIs to savings about 1.6.[33] Because the 2007 study focused on custom measures, we expected this measure of variability to represent a high end estimate for prescriptive measures. For sampling purposes we used an error ratio of 1.0, which should provided a more reasonable estimate of variance for the measures in this study. The tool also produced anticipated precision estimates for each group in the population. We provided precision estimates using each of the aforementioned error ratios in this memo: "optimistic precisions" employed the 1.0 error ratio, while "conservative precisions" employed the 1.6 error ratio.

Because the sample size was already determined for the NEI study, the tool was used to efficiently stratify and allocate the sample within the strata. The sampling unit was measure group installed at a site (a project), and the tool optimized the sample by selecting a higher proportion of projects with large estimated savings. This resulted in higher precision levels than a random sample within the measure group.

We employed the following steps to select a sample of 125 electric and 75 gas measures from respondents to the 2010 participant FR/SO2010 participant FR/SO survey. This approach allowed us to select a sample that preserved heterogeneity of the population while reducing the variance within sample segments.

Aggregate measure categories into 2010 participant FR/SO reporting categories

KEMA stratified respondents to the 2010 participant FR/SO2010 participant FR/SO survey (the previous study) according to measure groupings reported in the final report. The previous study stratified their sample frame by "measure categories[34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44]"

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[32] – Non-Electric Benefits of the Custom Projects Program A Look at the Effects of Custom Projects in Massachusetts. TecMarket Works. September 25, 2007.

[33] The *error ratio* measures the variability of individual NEI values around the ratio line defined by

NEI = (Constant) x (Savings).

An error ratio of 1.6 means that the standard deviation of NEI for a given savings level is 160% of the mean NEI estimated by this equation. For example, if the mean NEI is estimated to be 30% of the mean savings (constant = 0.30), individual NEI values would have a standard deviation 1.6 x 30% = 48% of their estimated savings.

[34] 2010 Cape Light Compact C&I Free-Ridership and Spillover Study Final Sample Plan. Tetra Tech. April 21, 2011

[35] 2010 New England Gas Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 12, 2011

[36] 2010 Nstar Free-Ridership and Spillover Study Proposed Sample Plan. Tetra Tech. March 4, 2011.

[37] 2010 Berkshire Gas Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 13, 2011.

[38] 2011 National Grid Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 16, 2011.

identified by the evaluation team and the individual PAs. The PAs later requested that measures be re-classified for reporting purposes, which we refer to as the 2010 participant FR/SO reporting categories[45]. Determining the representativeness of a sample stratified by this classification of measures required us to map respondents to the previous study and the population of measures to their respective 2010 participant FR/SO reporting categories.

Establish strata by 2011 reporting category and NEI expectation

Our sample design further stratified electric and gas measures within each 2010 participant FR/SO measure category into two groups which separated customers who expected NEIs prior to participation from those who did not expect NEIs. We used 2010 participant FR/SO2010 participant FR/SO survey responses to create separate strata based on participants' expectations for NEIs prior to participating in their respective program. This information allowed us to contrast NEI estimates and program attribution for groups who did and did not expect NEIs prior to participation, providing valuable information for examining the potential impact of NEIs on free-ridership rates and net NEIs.

Optimize sample by creating size of savings strata and allocate sample targets

Within each 2010 participant FR/SO reporting group by NEI expectation grouping, we further separated projects into groups based on energy savings. We used KEMA's MBSS software to identify the critical values for defining size strata, and the desired number of completes from each stratum to achieve optimal precision. After determining the optimal overall precision we re-allocated target completes to better represent sub-populations with lower savings. While this improved precision in the smaller groups, it did sacrifice some of the overall precision.

ESTABLISHING TARGET COMPLETES FOR ELECTRIC AND GAS MEASURES

As discussed in the December 9, 2011 work plan, development of the sampling plan required the evaluation team to establish the target number of completed interviews for prescriptive electric and gas measures. KEMA recommended the following number of interviews from electric and gas measures:

- **Electric measures** – KEMA recommended completing 125 interviews for prescriptive electric measures in order to provide sufficient data to achieve an approximately 25 percent precision with an 80 percent confidence interval for electric measure NEI estimates;

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39 2010 Unitil Free-Ridership Study Proposed Sample Plan. Tetra Tech. April 8, 2011.
40 2010 Columbia Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 11, 2011.
41 National Grid Free-Ridership and Spillover Study Proposed Sample Plan. Tetra Tech. March 4, 2011.
42 2011 Unitil Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 9, 2011.
43 2010 Nstar Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 13, 2011.
44 2010 Western Massachusetts Electric Company Free-Ridership Study Sample Plan. Tetra Tech. July 15, 2011.
45 We refer to the re-classified measure groupings as "2011 FR/SO reporting categories." This classification was defined by the PAs and the evaluation team during the reporting phase of that study. While KEMA will aggregate some of the 2011 FR/SO reporting categories for sampling, we will not re-assign measures to new disaggregated categories.

- **Gas measures** – KEMA recommended completing 75 interviews for prescriptive gas measures in order to provide sufficient data to achieve approximately 25 percent precision with an 80 percent confidence interval for gas measure NEI estimates.

PRESCRIPTIVE ELECTRIC MEASURE SAMPLE DESIGN

This section reports the results of implementing the sampling approach to define the sample of electric measures for the study.

KEMA used the eight reporting categories for electric measures from the 2010 participant FR/SO study in the sample design as shown in **Appendix Table B-1**. To identify these reporting categories, we adopted the same mapping of measures to end uses for each PA used in the 2010 participant FR/SO study.

Appendix Table B-1 2010 participant FR/SO Reporting Measure Categories - Electric

2011 FR/SO Reporting Category
Compressed Air
HVAC
Lighting
Motors and Drives
Process
Refrigeration
Building Envelope
Comprehensive

Appendix Table B-2 shows the distribution of projects by reporting category and their response to the NEI expectation question NE1 in the 2010 participant FR/SO2010 participant FR/SO survey. We targeted completes for each 2010 participant FR/SO reporting category by NEI expectation.

Appendix Table B-2 2010 participant FR/SO2010 participant FR/SO survey Responses by NEI Expectation and 2010 participant FR/SO Reporting Category - Electric

2011 FR/SO Resporting Category	NEI Expectation		Total FR/SO Survey Responses
	Expected	Did Not Expect	
Compressed Air	6	10	16
HVAC	20	42	62
Lighting	286	483	769
Motors and Drives	58	52	110
Process	2	0	2
Refrigeration	10	48	58
Building Envelope	1	0	1
Comprehensive	87	172	259
Total	**470**	**807**	**1,277**

Next, KEMA used the MBSS tool to identify critical kWh values to optimally segment the sample by kWh savings. Appendix Table B-3 shows the final stratification of the sample, defined by the combination of 2010 participant FR/SO reporting category and NEI expectation, and kWh savings as reported in the tracking data. The sampling process identified 23 strata for the NEI sample (Appendix Table B-3). KEMA allocated the 125 completed interviews to these 23 strata.

Because lighting projects make up 77 percent of savings in the population, simply setting target complete according to the optimal allocation for overall precision would have allocated roughly 75 percent of the sample to lighting projects. In order to improve precisions for non-lighting measures, we re-allocated a portion of the lighting targets to other measure categories. We also re-allocated a small number of targets to improve anticipated precision for participant expected NEIs, but this did not substantially change overall precision. While these changes resulted in a lessening of the anticipated overall precision (from 11 percent to 26 percent at the 80 percent confidence level), it improved precision for the non-lighting categories and participant expected NEIs substantially.

Appendix Table B-3 Final Stratification – Prescriptive Electric

2011 FR/SO Reporting Category	NEI Expectation	Size	2011 FR/SO Completes	Min kWh	Max kWh	Percent Pop Weighted kWh	NEI Study Target Completes
Compressed Air	Expected	All	6	11,302	44,990	0.1%	2
	Not Expected	All	10	14,420	180,456	0.2%	2
HVAC	Expected	Small	15	1,523	140,499	0.4%	5
		Medium	4	154,886	251,406	0.6%	4
		Large	1	871,825	871,825	0.3%	1
	Not Expected	Small	30	800	306,947	1.7%	6
		Large	12	332,683	509,037	2.2%	5
Lighting	Expected	Small	226	219	124,902	11.8%	12
		Large	60	125,746	2,023,465	18.7%	12
	Not Expected	Small	393	70	118,613	17.2%	13
		Large	90	122,148	1,570,270	29.8%	13
Motors and Drives	Expected	Small	44	6,819	146,588	1.5%	6
		Large	14	164,359	378,717	2.2%	6
	Not Expected	Small	42	5,842	761,883	3.9%	8
		Large	10	761,883	952,909	5.0%	7
Process	Expected	All	2	101,856	230,310	0.3%	2
Refrigeration	Expected	All	10	1,057	19,342	0.0%	2
	Not Expected	All	48	358	20,455	0.2%	2
Building Envelope	Expected	All	1	375	375	0.0%	1
Comprehensive	Expected	Small	62	298	18,248	0.6%	4
		Large	25	19,748	137,402	0.9%	3
	Not Expected	Small	116	262	19,599	1.0%	5
		Large	56	20,596	90,336	1.5%	4
Total			**1,277**	**70**	**2,023,465**	**100.0%**	**125**

PRESCRIPTIVE GAS MEASURE SAMPLE DESIGN

KEMA used the four reporting categories for gas measures from the 2010 participant FR/SO study in the sample design as shown in Appendix Table B-4. To identify these reporting categories, we adopted the same mapping of measures to end uses for each PA used in the 2010 participant FR/SO study.

Appendix Table B-4 2010 participant FR/SO Gas Reporting Categories

2011 FR/SO Reporting Category
Building Envelope
HVAC
Water Heating
Process

Appendix Table B-5 shows the distribution of gas projects by reporting category and their response to the NEI expectation question NE1 in the 2010 participant FR/SO2010 participant FR/SO survey.

Appendix Table B-5 2010 participant FR/SO2010 participant FR/SO survey Responses by NEI Expectation and 2010 participant FR/SO Reporting Category -Gas

2011 FR/SO Reporting Category	NEI Expectation		Total 2011 FR/SO Survey Responses
	Expected	Did Not Expect	
Building Envelope	0	3	3
HVAC	44	72	116
Water Heater	29	80	109
Process	1	0	1
Total	**74**	**155**	**229**

Appendix Table B-6 shows the final stratification of the gas sample, defined by the combination of 2010 participant FR/SO reporting category, NEI expectation, and therm savings (as reported in the tracking data). This sampling process provided for the nine total strata for the NEI sample seen in Appendix Table B-6. KEMA allocated the 75 completed interviews to these nine strata. The only re-allocation from the optimal sample design was to improve anticipated precision when the participant expected NEIs. This resulted in overall precision worsening from 14 percent to 26 percent.

Appendix Table B-6 Final Stratification – Prescriptive Gas

2011 FR/SO Reporting Category	NEI Expectation	Size	2011 FR/SO Completes	Min Therms	Max Therms	Percent Pop Weighted Therms	NEI Study Target Completes
Building Envelope	Not Expected	All	3	18	840	0.4%	1
HVAC	Expected	Small	38	8	1,467	7.2%	10
		Large	6	1,566	2,934	11.4%	6
	Not Expected	Small	65	15	1,440	10.8%	15
		Large	7	1,488	7,440	21.8%	7
Water Heater	Expected	Small	29	17	618	3.9%	5
	Not Expected	Small	68	17	386	15.8%	18
		Large	12	618	7,638	26.5%	12
Process	Expected	All	1	1,536	1,536	2.3%	1
Total			**229**	**8**	**7,638**	**100.0%**	**75**

POTENTIAL REPORTING CATEGORIES FOR PRESCRIPTIVE MEASURES

Our ability to provide stable NEI estimates depended upon the number of observations sampled and the variation in NEI values per unit of savings for a given level of aggregation of measures. While we could compute NEI estimates for any specified measure category contained in the sample data, estimates for finer categories in general will have worse precision for a given confidence level (eg. 80 percent confidence level). In this section, we presented the expected precision of electric and gas NEI estimates for different measure groupings. In the tables that follow, the expected precision X for an 80 percent confidence interval indicates that we are 80 percent confident that the true NEI value is within plus or minus X percent of the estimated value.

Electric measures

The sample size of 125 for the prescriptive electric programs would not include enough completed surveys to offer stable, meaningful results in all of the reporting categories used for the 2010 participant FR/SO study due to limited number of survey respondents and expected variation in NEI estimates in each category. Appendix Table B-7 below shows our proposed reporting groups and our anticipated precisions at the 80 percent confidence level for each grouping.

Appendix Table B-7 Proposed Measure Groupings for NEI Analysis – Prescriptive Electric

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
Lighting	769	50	77%	23%	37%
Motors and Drives	124	27	13%	33%	53%
HVAC	62	21	5%	31%	49%
Other	336	27	5%	32%	51%
Overall	**1,291**	**125**	**100%**	**18%**	**29%**

* Our optimistic precision estimates assumed an error ratio of 1.0, while the conservative precisions assumed an error ratio of 1.6.

In addition to reporting groups, we provided results by the expectation of NEIs as reported by respondents to the 2010 participant FR/SO2010 participant FR/SO survey. Appendix Table B-8 shows the expected precision for these two groups.

Appendix Table B-8 Expected Precisions by Expectation of NEIs – Prescriptive Electric

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
Expected	471	60	37%	27%	43%
Not Expected	820	65	63%	24%	39%
Overall	**1,291**	**125**	**100%**	**18%**	**29%**

* Our expected precisions assumed an error ratio of 1.0, while the conservative precisions assumed an error ratio of 1.6.

Gas measures

The sample size of 75 for the prescriptive gas programs would not include enough completed surveys to offer meaningful results in all of the reporting categories used for the 2010 participant FR/SO study. Appendix Table B-9 below shows our proposed reporting groups and our anticipated precisions at the 80 percent confidence level for each grouping.

Appendix Table B-9 Proposed Measure Groupings for NEI Analysis – Prescriptive Gas

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
HVAC	116	38	51%	35%	39%
Water Heater	109	35	46%	41%	46%
Other	4	2	3%	167%	187%
Overall	**208**	**75**	**100%**	**26%**	**30%**

* Optimistic precisions assumed an error ratio of 1.0, while the conservative precisions assumed an error ratio of 1.6.

In addition to reporting groups, we provided results by the expectation of NEIs as reported by respondents to the 2010 participant FR/SO2010 participant FR/SO survey. Appendix Table B-10 shows the expected precision for these two groups.

Appendix Table B-10 Expected Precisions by Expectation of NEIs – Prescriptive Gas

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
Expected	74	22	25%	45%	51%
Not Expected	155	53	75%	32%	36%
Overall	**208**	**75**	**100%**	**26%**	**30%**

* Our expected precisions assumed an error ratio of 1.0, while the conservative precisions assumed an error ratio of 1.6.

ALTERNATIVE SAMPLE DESIGNS

This section presented two alternative sample designs for electric measures and one alternative sample design for gas measures that provided increased estimates of precision by expanding the number of completed interviews. In all scenarios the timing of the final report remained the same.

Electric Measures

Scenario 1: Original Budget Scenario

The original budget allowed for 125 completed interviews as detailed above in Appendix Table B-7.

Scenario 2: High Precision

Scenario 2 provided the highest anticipated precisions considered, and the highest cost. It increased the number of completes almost fourfold from 125 to 443. This scenario provided for a census of all non-lighting 2010 participant FR/SO reporting category, while including completed interviews for lighting measures to achieve 80/11 precision for lighting.[46] The number of completes for optimal precision and the expected and conservative estimates of precision for each or the proposed NEI Study reporting groups are shown below in Appendix Table B-11.

[46] Improving expected precision to 80/10 for lighting would require an additional 26 completes.

Appendix Table B-11 Expected Precisions – Prescriptive Electric Scenario 2: High Precision

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
Lighting	769	128	77%	11%	18%
Motors and Drives	124	67	13%	7%	21%
HVAC	62	38	5%	16%	34%
Other	336	210	5%	9%	19%
Overall	**1,291**	**443**	**100%**	**9%**	**14%**

* Optimistic precisions assumed an error ratio of 1.0 and used an expected response rate of 2/3 in the measure groups where we took a census, while the conservative precisions assumed an error ratio of 1.6 and a response rate of 1/2 in the measure groups where we took a census.

Scenario 3: Recommended approach

Scenario 3, the approach we recommend if the scope is expanded, combined the first two scenarios to limit the increase in costs, while increasing precision in the measures categories that matter most. It provided similar overall precision to Scenario 2 at greatly reduced cost. This scenario targeted 317 completed interviews, keeping the same number of targeted completes for lighting presented in Scenario 2 and also retaining Scenario 2's census of all non-lighting 2010 participant FR/SO categories with the exception of the comprehensive category.

We reduced the targets for the comprehensive 2010 participant FR/SO measure category to the level of Scenario 1. The comprehensive category was a catch-all "other" categories with a variety of small measures in it. In total it represents less than four percent of savings across 2011 programs, but included almost one fourth of the total installed measures. We chose to reduce the targeted number of completed interviews in this category because the combination of low savings and a high number of varied measures makes achieving precise results for this category both expensive and less meaningful.

Our recommended number of completes for each or the proposed NEI Study reporting groups are shown below in Appendix Table B-12. We again presented both optimistic and conservative estimates of expected precision, based on a 1.0 and 1.6 error ratios, respectively.

Appendix Table B-12 Expected Precisions – Prescriptive Electric Scenario 3: Recommended Approach

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
Lighting	769	128	77%	11%	18%
Motors and Drives	124	67	13%	7%	21%
HVAC	62	38	5%	16%	34%
Other	336	64	5%	31%	51%
Overall	**1,291**	**297**	**100%**	**9%**	**15%**

* Optimistic precisions assumed an error ratio of 1.0 and used an expected response rate of 2/3 in the measure groups where we took a census, while the conservative precisions assumed an error ratio of 1.6 and a response rate of 1/2 in the measure groups where we took a census.

Scenario Comparison

Appendix Table B-13 shows precisions by 2010 participant FR/SO study reporting groups. While we recommended aggregating these groups in some way similar to the proposed NEI study reporting groups above (depending on the actual precision of the results), these disaggregated precision estimates assisted in selecting which sampling scenario to pursue.

Appendix Table B-13 Expected Precisions – Prescriptive Electric Scenario Comparison

2010 participant FR/SO Study Reporting Group	Percent of Pop Weighted kWh	Scenario 1 (Original Budget) Precision (Expected*/ Conservative*)			Scenario 2 (High Precision) Precision (Optimistic*/ Conservative*)			Scenario 3 (Recommended) Precision (Optimistic*/ Conservative*)		
Compressed Air	0.3%	78%	/	125%	29%	/	70%	29%	/	70%
HVAC	5.2%	31%	/	49%	16%	/	34%	16%	/	34%
Lighting	77.3%	23%	/	37%	11%	/	18%	11%	/	18%
Motors and Drives	12.8%	33%	/	53%	7%	/	21%	11%	/	21%
Process	0.3%	76%	/	122%	76%	/	195%	76%	/	195%
Refrigeration	0.2%	96%	/	154%	17%	/	34%	17%	/	34%
Building Envelope	0.0%	0%	/	0%	0%	/	0%	0%	/	0%
Comprehensive	3.9%	38%	/	60%	8%	/	16%	38%	/	60%
Overall	**100.0%**	**18%**	**/**	**29%**	**9%**	**/**	**14%**	**9%**	**/**	**15%**

* Optimistic precisions assumed an error ratio of 1.0 and used an expected response rate of 2/3 in the measure groups where we took a census, while the conservative precisions assumed an error ratio of 1.6 and a response rate of 1/2 in the measure groups where we took a census.

In Appendix Table B-14 we presented the total number of completes and the additional budget required for each of the electric scenarios.

Appendix Table B-14 Additional Cost Estimates – Prescriptive Electric Scenarios

Scenario		Target Completes	Additional Funds Required	Precision Optimistic	Precision Conservative
1	Original Budget	125	$0	18%	29%
2	High Precision	443	$133,000	9%	14%
3	Recommended	297	$72,000	9%	15%

Gas

Scenario 1: Original Budget Scenario

The original budget allowed for 75 completed surveys as detailed above in Appendix Table B-9.

Scenario 2: Recommended approach

We recommend taking a census of gas measures. We estimated that a census of measures would provide between 9 percent and 15 percent overall relative precision depending on the number of completed surveys achieved and the observed variance in responses. Appendix Table B-15 shows the number of completed interviews and the estimated relative precisions based on taking a census of all gas measures completed in the 2010 participant FR/SO study.

Appendix Table B-15 Expected Precisions – Prescriptive Gas Scenario 2: Recommended Approach

NEI Study Reporting Group	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Weighted kWh	Optimistic Precision at 80% Confidence*	Conservative Precision at 80% Confidence*
HVAC	116	77	51%	11%	18%
Water Heater	109	73	46%	15%	24%
Other	4	3	3%	103%	167%
Overall	**208**	**153**	**100%**	**9%**	**15%**

* Optimistic precisions assumed an error ratio of 1.0 and used an expected response rate of 2/3 in the measure groups where we took a census, while the conservative precisions assumed an error ratio of 1.6 and a response rate of 1/2 in the measure groups where we took a census.

Scenario Comparison

Appendix Table B-16 shows precisions by 2010 participant FR/SO study reporting groups. While we recommend aggregating these groups to the proposed NEI study reporting groups above (depending on the actual precision of the results), these disaggregated precision estimates assisted in selecting which sampling scenario to pursue.

Appendix Table B-16 Expected Precisions – Prescriptive Electric Scenario Comparison

2010 participant FR/SO Study Reporting Group	Percent of Pop Weighted kWh	Scenario 1 Precision (Optimistic*/ Conservative*)	Scenario 2 Precision (Optimistic*/ Conservative*)
Building Envelope	0.4%	219% / 246%	79% / 219%
HVAC	51.1%	35% / 39%	11% / 18%
Water Heater	46.2%	41% / 46%	15% / 24%
Process	2.3%	190% / 214%	119% / 190%
Overall	**100.0%**	**26% / 30%**	**9% / 15%**

* Optimistic precisions assumed an error ratio of 1.0 and used an expected response rate of 2/3 in the measure groups where we took a census, while the conservative precisions assumed an error ratio of 1.6 and a response rate of 1/2 in the measure groups where we took a census.

In Appendix Table B-17 we presented the total number of completes and the additional budget required for each of the gas scenarios.

Appendix Table B-17 Additional Cost Estimates – Prescriptive Gas Scenarios

Scenario		Target Completes	Additional Funds Required	Precision Optimistic	Precision Conservative
1	Original Budget	75	$0	26%	30%
2	Recommended	153	$34,000	9%	15%

Appendix C. DETAILED SAMPLING PLAN: CUSTOM MEASURES

INTRODUCTION

This memo presented the sampling approach for the Non-Energy Impacts (NEI) interviews associated with custom measures for the Massachusetts Multi-Evaluation Tasks for Massachusetts Energy Efficiency Programs in the Special Cross-sector Studies Area. We drew the custom measure NEI sample from the following:

- DNV KEMA used a census of custom measure NEI sample from the 1,205 custom projects that received surveys during the 2010 participant FR/SO. This enabled us to examine potential differences in the free efficiency ridership rate on savings and NEIs.
- We supplemented this sample with additional measures that did not receive surveys during the 2010 participant FR/SO in order to obtain better precision in our estimates.

The proposed custom measure NEI study included 461 completed interviews across electric and gas projects. The sampling plan presented in this memo included the following:

1. We provided a range for the expected precision of NEI estimates by varying the error ratio. Our "conservative" estimate assumes an error ratio of 1.6, based on the 2007 custom NEBs study.
2. We also presented the an optimistic estimate of precision which assumes an error ratio of 1.2, which may be more representative of variance within strata for this study due to our ability to classify projects by reporting category, program, and savings levels.

This memo is divided into the following sections:

- **Overview of Custom Measure Sampling Approach**: Presented an overview of the general sampling approach;
- **Custom Electric Measure Sample Design**: Provided details of the proposed sampling approach for the electric measure sample;
- **Custom Gas Measure Sample Design**: Provided details of the proposed sampling approach for the gas measure sample; and
- **Custom Study Costs**: Presented the budget for the proposed custom study.

OVERVIEW OF CUSTOM MEASURE SAMPLING APPROACH

DNV KEMA employed a proprietary sampling tool that uses Model Based Statistical Sampling (MBSS) to produce an optimally allocated sample for stratified ratio estimation. The tool maximized precision based on the population characteristics (in this case, gross estimated savings) and the expected variance in the population on the variable being estimated. For this study, that variable was non-energy impacts. This tool is appropriate when there is a relationship between the characteristic and the variable of interest. The 2007 TecMarket Works NEI study found a low correlation between NEIs and energy savings; however, given a larger sample size we can accurately determine the ratio of NEIs to savings for "typical" cases.[47] The standard deviation, mean and correlation reported in the 2007 study found an error ratio for the ratio of NEIs to savings of approximately 1.6.[48] DNV KEMA expected this measure of variability can be reduced by stratifying the population to a finer level. For sampling purposes we used an error ratio of 1.2, which provided a more optimistic estimate of variance for the measures in this study. The tool also produced anticipated precision estimates for each group in the population. We provided precision estimates using each of the aforementioned error ratios in this memo: "optimistic precisions" employed the 1.2 error ratio, while "conservative precisions" employed the 1.6 error ratio.

The tool was used to determine the sample sizes and efficiently stratify and allocate the sample within the strata. The sampling unit was measure group installed at a site (a project), and the tool optimized the sample by selecting a higher proportion of projects with large estimated savings. This resulted in higher precision levels than a random sample within the measure group.

The following steps were followed to select our sample from projects eligible for the 2010 participant FR/SO2010 participant FR/SO survey. This approach allowed us to select a sample that preserved heterogeneity of the population while reducing the variance within sample segments.

Assigned measures to 2010 participant FR/SO certainty and non-certainty strata

Most of the custom measures eligible for the study were sampled for the 2010 participant FR/SO2010 participant FR/SO survey with certainty (a census was attempted for most programs). Based on the sample plans for the 2010 participant FR/SO study, DNV KEMA defined measures as "sampled with certainty" when we determined that surveys were attempted with all measures for a particular program or measure type within a program. We gave priority to measures completed in the 2010 participant FR/SO study over the additional sample in order to leverage the attribution results from the 2010 participant FR/SO study.

Assigned measures PA and program

DNV KEMA defined strata based on PA and program to reflect the heterogeneity of custom measures installed by the different PAs and programs. This also better aligned the NEI strata with those used in the 2010 participant FR/SO analysis.

Aggregated measure categories into 2010 participant FR/SO reporting categories

Where possible, DNV KEMA assigned measures to measure groupings consistent with 2010 participant FR/SO (the previous study) final report. The previous study stratified their sample frame by "measure categories[49] [50] [51] [52] [53] [54] [55] [56] [57] [58] [59]" identified by the evaluation team and

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[47] – Non-Electric Benefits of the Custom Projects Program A Look at the Effects of Custom Projects in Massachusetts. TecMarket Works. September 25, 2007.

[48] The *error ratio* measures the variability of individual NEI values around the ratio line defined by

NEI = (Constant) x (Savings).

An error ratio of 1.6 means that the standard deviation of NEI for a given savings level is 160% of the mean NEI estimated by this equation. For example, if the mean NEI is estimated to be 30% of the mean savings (constant = 0.30), individual NEI values would have a standard deviation 1.6 x 30% = 48% of their estimated savings.

[49] 2010 Cape Light Compact C&I Free-Ridership and Spillover Study Final Sample Plan. Tetra Tech. April 21, 2011

the individual PAs. The PAs later requested that measures be re-classified for reporting purposes, which we refer to as the 2010 participant FR/SO reporting categories.[60] A small subset of electric measures either did not have the necessary information for this classification, nor had information that the measure fell into multiple categories. We included this subset of measures in the "Comprehensive" sampling category. We mapped respondents to the previous study and the population of measures to their respective 2010 participant FR/SO reporting categories.

Optimized sample by creating size of savings strata and allocate sample targets

Within each grouping defined by Certainty, PA, Program and 2010 participant FR/SO reporting group, the projects were further separated into groups based on energy savings. DNV KEMA's MBSS software was used to identify the critical values for defining strata by size (savings), and the desired number of completes from each stratum to achieve optimal precision. After determining the optimal overall precision, sample sizes for a few strata were increased to ensure better representation of the sub-populations with lower savings.

CUSTOM ELECTRIC MEASURE SAMPLE DESIGN

This section reports the results of implementing the sampling approach to define the sample of electric measures for the study.

Certainty vs. Non-Certainty by program and PA

KEMA used the eight reporting categories for electric measures from the 2010 participant FR/SO study in the sample design as shown in Appendix Table C-1.

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[50] 2010 New England Gas Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 12, 2011
[51] 2010 Nstar Free-Ridership and Spillover Study Proposed Sample Plan. Tetra Tech. March 4, 2011.
[52] 2010 Berkshire Gas Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 13, 2011.
[53] 2011 National Grid Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 16, 2011.
[54] 2010 Unitil Free-Ridership Study Proposed Sample Plan. Tetra Tech. April 8, 2011.
[55] 2010 Columbia Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 11, 2011.
[56] National Grid Free-Ridership and Spillover Study Proposed Sample Plan. Tetra Tech. March 4, 2011.
[57] 2011 Unitil Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 9, 2011.
[58] 2010 Nstar Free-Ridership and Spillover Gas Study Proposed Sample Plan. Tetra Tech. July 13, 2011.
[59] 2010 Western Massachusetts Electric Company Free-Ridership Study Sample Plan. Tetra Tech. July 15, 2011.
[60] We refer to the re-classified measure groupings as "2011 FR/SO reporting categories." This classification was defined by the PAs and the evaluation team during the reporting phase of that study. While KEMA will aggregate some of the 2011 FR/SO reporting categories for sampling, we will not re-assign measures to new disaggregated categories.

Appendix Table C-1 2010 participant FR/SO Reporting Measure Categories - Electric

2011 FR/SO Reporting Category
Compressed Air
HVAC
Lighting
Motors and Drives
Process
Refrigeration
Building Envelope
Comprehensive

Next, DNV KEMA used the MBSS tool to identify critical kWh values to optimally segment the sample by kWh savings. The sampling process identified 74 strata for the NEI sample. Appendix Table C-2 shows the final stratification without the kWh savings segmentation. DNV KEMA allocated 310 completed interviews to these 74 strata.

Appendix Table C-2 Final Stratification – Custom Electric

PA	Program	2010 participant FR/SO Reporting Category	Certainty	Pop Measures	Percent of Pop kWh	NEI Study Target Completes
CLC	Med. and Large C&I Retrofit	Lighting	Yes	1	0%	1
	Small C&I Retrofit	Lighting	No	1	0%	1
		Motors and Drives	Yes	2	0%	1
	Small Govt. Retrofit	Lighting	No	1	0%	1
Ngrid	EI	Building Envelope	No	5	0%	3
		CHP/Cogen	No	11	10%	8
		Compressed Air	No	12	4%	8
		HVAC	No	42	11%	19
		Lighting	No	97	6%	19
		Motors and Drives	No	72	9%	31
		Process	No	15	4%	10
		Refrigeration	No	28	2%	16
		Other	No	23	5%	10
Nstar	BS	CHP/Cogen	No	4	1%	3
		Compressed Air	No	3	0%	2
		HVAC	No	67	17%	28
		Lighting	No	220	19%	69
		Motors and Drives	No	10	2%	7
		Process	No	4	1%	3
		Refrigeration	No	62	4%	30
		Other	No	4	1%	3
	SBS	HVAC	No	1	0%	1
		Refrigeration	No	194	2%	34
Unitil	Large C&I Retrofit	Process	Yes	2	0%	2
Overall				**881**	**100%**	**310**

In determining the final sample size and distribution, we attempted to target a relative precision of 80/10 for each reporting category using optimistic assumptions (1.2 error ratio). For the building envelope, CHP/Cogen, Compressed Air, Process and Comprehensive categories, an expected relative precision of 80/10 was unattainable even with a census of measures. Appendix Table C-3 shows the expected precisions at 80 percent confidence for the proposed custom electric sample for each 2010 participant FR/SO Reporting Groups. This stratification resulted in interviews from 310 completed measures to achieve the desired level of precision.

Appendix Table C-3 Expected Precisions – Custom Electric Sample by 2010 participant FR/SO Reporting Group

2010 participant FR/SO Reporting Group	Pop Measures	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop kWh	Optimistic Precision at 80% Confidence	Conservative Precision at 80% Confidence
Building Envelope	5	1	3	0%	57%	76%
CHP/Cogen	15	5	11	11%	15%	41%
Compressed Air	15	6	10	5%	11%	33%
HVAC	110	36	48	28%	10%	13%
Lighting	320	79	91	25%	10%	13%
Motors and Drives	84	26	39	10%	10%	15%
Process	21	11	15	6%	16%	34%
Refrigeration	284	73	80	8%	10%	14%
Other	27	8	13	7%	26%	36%
Overall	**881**	**245**	**310**	**100%**	**5%**	**8%**

CUSTOM GAS MEASURE SAMPLE DESIGN

DNV KEMA used the four reporting categories for gas measures from the 2010 participant FR/SO study in the sample design as shown in Appendix Table C-4. To identify these reporting categories, we adopted the same mapping of measures to end uses for each PA used in the 2010 participant FR/SO study.

Appendix Table C-4 2010 participant FR/SO Gas Reporting Categories

2010 participant FR/SO Reporting Category
Building Envelope
HVAC
Water Heater
Process
Other

Appendix Table C-5 shows the final stratification of the gas sample, defined by the combination of PA, program, 2010 participant FR/SO reporting category, and therm savings (as reported in the tracking data). Whereas the 2010 participant FR/SO sample was primarily not a census, a census of custom gas projects were included in this study, except for HVAC, which did not require a census. The sampling process provided for 50 total strata. The NEI sample in Table 5 shows the segmentation of measures prior to adding the segmentation by therm savings. DNV KEMA allocated the 151 completed interviews across the strata.

Appendix Table C-5 Final Stratification – Custom Gas

PA	Program	2010 participant FR/SO Reporting Category	Pop Measures	Percent of Pop Therms	NEI Study Target Completes
Berkshire Gas	Custom	Building Envelope	7	0%	4
		HVAC	12	3%	8
		Water Heater	3	0%	1
		Process	1	0%	1
Columbia Gas	Large Custom	Building Envelope	3	1%	2
		HVAC	18	29%	12
		Water Heater	2	3%	1
		Process	3	5%	2
	Small Custom	Building Envelope	31	2%	20
		HVAC	61	8%	12
		Water Heater	35	1%	10
NStar	Custom Gas	Building Envelope	7	1%	4
		HVAC	50	21%	22
		Water Heater	6	2%	4
		Other	8	5%	5
NGrid	Retro-C	Building Envelope	34	2%	22
		HVAC	29	13%	12
		Water Heater	9	1%	6
		Process	4	2%	2
New England Gas	Custom	Process	1	1%	1
Overall			**324**	**100%**	**151**

In determining the final sample size and distribution, we attempted to target a relative precision of 80/10 for each reporting category using optimistic assumptions. The only 2010 participant FR/SO reporting category for which we did not conduct a census was HVAC. For HVAC, we were able to achieve 80/10 precision with optimistic assumptions by interviewing less than a census. Appendix Table C-6 shows the expected precisions at 80 percent confidence for the proposed custom gas sample for each 2010 participant FR/SO Reporting Group.

Appendix Table C-6 Expected Precisions – Custom Gas Sample by 2010 participant FR/SO Reporting Group

2010 participant FR/SO Study Reporting Group	Pop Measures	2010 participant FR/SO Completes	NEI Study Target Completes	Percent of Pop Therms	Expected Precision at 80% Confidence	Conservative Precision at 80% Confidence
Building Envelope	82	38	52	6%	13%	17%
HVAC	170	49	66	74%	10%	13%
Water Heater	55	18	22	8%	48%	64%
Process	9	1	6	8%	28%	37%
Other	8	0	5	5%	30%	41%
Overall	**324**	**106**	**151**	**100%**	**8%**	**11%**

Appendix D. PRESCRIPTIVE MEASURE INTERVIEW GUIDE

MA NEI Interview

Contact________________________________

Company: ______________________________

Clean_Phone: ______________________________

Address: ______________________________

Alternate phone: ____________________________

Reporting Category 1: ___________________ Measure ID1:____________________

Reporting Category 2 ___________________ Measure ID2:____________________

PA Name: __ Program Name:___ _________

Participation Date: ____

Call #	Date	Time	Notes (include message left, best time to call, best way to contact, and whether survey was completed)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Final Disposition: O complete O refused O no answer O mid-terminate O other (specify______________________________________)

Interview Length:________

Purpose of the Interview

Determine whether measures resulted in non-energy impacts (NEIs –"any positive or negative effect beyond energy savings that are attributable to energy efficiency programs")

Identify sources of NEIs that resulted from the installed measures

Obtain estimates of non-energy impacts (NEI)

Seek monetized non-energy benefits or costs

If respondents cannot monetize NEIs, guide respondents through relevant probes to obtain the necessary information for imputing monetized estimates of NEI;

Obtain measures of spillover – Participant spillover is energy savings resulting from program influenced installation of energy efficiency measures that did not receive program incentives. We will obtain estimates of both like and un-like spillover.

Like spillover –energy savings resulting from program influenced installation of energy-efficient equipment of the same type (i.e. the same measure, capacity, and efficiency level)

Unlike spillover –energy savings resulting from program influenced installation of energy-efficient equipment of the a different type (i.e. different measure, capacity, or efficiency level)

Introduction and Screening

[Get <<CONTACT>> on the phone]

Hello, my name is __ and I am calling from KEMA Consulting on behalf of <<PA NAME>> and <<PROGRAM>>

I'm calling to get some feedback on how the energy efficiency improvements you made through <<PROGRAM>> have affected your organization's costs and revenues. Someone else from KEMA called you a few days ago to set up this interview.

Are you still the person at <<COMPANY>> most familiar with the outcomes of your organization's participation and experience with the <<PROGRAM>> program?

[If necessary] Last Spring, someone from the evaluation team spoke you about your participation in the <<PA NAME>> <<PROGRAM>> program around <<PARTICIPATION DATE>>.

[If "No"] Who is the right person to talk to? [Get name and contact information. Attempt to reach]

[Once correct person on phone]: All of your answers are confidential and will only be reported in aggregate.

[If asked]: You can verify the legitimacy of this research by calling ____________ at ____________

[If asked]: KEMA is an independent contractor hired to do this research.

[If different contact, record information below]

Name:__ ____

Phone: ___________________________; Alt Phone:__________________________________

Address:

____

About the Respondent

Let's start by getting a little information about your organization and you. These questions help us put the rest of your answers in context.

F1. What is the major economic activity at <<ADDRESS>>?

F2. How many full-time equivalent employees work at <<ADDRESS>>? [Bracket if don't know. Start at 100 employees and go up or down]

F3. What is the total square footage of conditioned space at <<ADDRESS>>? [Bracket if don't know. Start at 10,000 square feet and go up or down.]

AR1. What is your job title?

AR2. What are your responsibilities?

AR3. How long have you done that?

Equipment Verification

My records show that you have installed the following measures through <<PROGRAM>>:

MEASURE 1).________________________

MEASURE 2:________________________

MEASURE 3:________________________

MEASURE 4: _______________________

MEASURE 5:________________________

MEASURE 6:________________________

MEASURE 7:________________________

MEASURE 8:________________________

EV2. Is this equipment still installed?

1 Yes [Go to EV5]

2	No	[Go to EV3]
97	Don't know	[Ask for alternate contact who could answer]
98	Refused	[Ask for alternate contact who could answer]

EV3. Why was it removed?

EV4. What, if anything, did you install in its place? [Skip to instructions after EV6.]

EV5. Is this equipment still operational?

1	Yes	[Go to NEI section]
2	No	[Go to EV6]
97	Don't know	[Ask for alternate contact who could answer]
98	Refused	[Ask for alternate contact who could answer]

EV6. Why not?

[Continue survey with any measures still installed.

If all measures no longer installed, ask NEI sections if reason for removal might be relevant to NEI. For example, *"It increased O&M costs too much."* If reason for removal not relevant to NEI, end interview.]

NEI Questions

[This section is about potential NEIs associated with the measures verified in the EV section above. If a multi location contact (i.e. one contact with multiple locations each participating in programs), try to get them to talk about the measures in terms of the average effects across measure groups (lighting, hvac, refrigeration, motors, compressed air, building envelope, water, process, and comprehensive). If they are unable to do that, get them to talk about MEASURE CAT 1 and MEASURE CAT 2 specifically for as many locations as possible]

DK = Don't know]

Now I'd like to ask you some questions about possible non-energy effects associated with the installation of these measures. By non-energy effects, I mean costs or benefits other than savings on your energy bills that your organization realized as a result of installing these measures. We're trying to estimate monetary costs or benefits, so for some of these categories, I'm going to try to convert time into money.

First, I'm going to go through a checklist of cost and benefit categories and ask you if your organization realized any costs or benefits in each one. Then we'll go back through and explore each relevant category in more depth.

You're going to need to explore all of the following non-electric resources. Money is applicable to all NEI sections. Water should mostly be covered in the Water Usage section. The MMBTU resources are probably in Other Costs, but could be spread throughout the entire survey.

Non Electric Resources, 2010							
Money	Water (gallons)	MMBTU					
		Avoided Natural Gas	No. 2 Distillate	No. 4 Fuel Oil	Propane	Wood	Kerosene

NEI Table1

Did your organization experience any changes in each of these categories because of any of the *high efficiency* <MEASURE CAT 1> / <MEASURE CAT 2> you installed?

[In the table below, write in the measure group or the measure that they answer about into the title row.

As you go through table, read the definition for each NEI category

Go through all the categories for Measure Cat 1 then come back and go through them a 2nd time for Measure Cat 2]

Question #	Category	Measure Cat 1	Measure Cat 2	Definition
OM1.	Annual operations and maintenance costs?	1.Yes 2.No 97. Don't know → [Ask for alternate contact who could answer] 98.Refused	1.Yes 2.No 97. Don't know → [Ask for alternate contact who could answer] 98.Refused	Anything that is spent (both time and parts) on maintaining an existing equipment, like installing new light bulbs or tuning up an air conditioner. This could be work done by contractors or in-house staff. Buying new light bulbs would be included, but new fixtures would NOT be included
LA1.	Administration costs?			The company's time costs from the back office people, such as accounting
SH1.	Materials handling?			Time and costs for people in the loading docks and warehouses
TM1.	Materials movement?			Time and costs (gas, vehicles, pay) for truck drivers, both deliveries and pickups
OL1.	Other labor?			Any labor not included in O&M, Administration, materials handling, or materials movement
FW1.	Water usage and wastewater?			Utility charges for water usage and wastewater
SD1.	Product spoilage?			Costs for lost or damaged product
SW1.	Waste disposal?			Costs for disposal of all solid and gaseous wastes (i.e. pollution)

IL1.	Fees?			Includes insurance, inspections, permits, and legal fees
OC1.	Other costs?			Includes any other costs we have not yet discussed
PR1.	Sales?			Sales revenues
RR1.	Rent revenues?			Revenue associated with rent
OR1.	Other revenue?			Includes any revenues from any sources we have not yet discussed

[Ask each of the next sections if change indicated in table above.]

NEI Questions –Operations and Maintenance

[This section is only for the measure(s) that were covered in the 2010 survey. You will ask respondents about potential NEIs associated with the measures verified in the EV section above. Again, respondents will be asked about NEIs associated with up to two measure categories only, *unless they are a multi-address contact.* If more than two measures were installed, then we restricted the sample to only two.

Reread the definition for this section when you get here.

This section refers to anything that's spent (both time and parts) maintaining an existing equipment, like installing new light bulbs or tuning up an air conditioner. This could be work done by contractors or in-house staff. Buying new light bulbs would be included, but new fixtures would NOT be included.]

OPERATIONS AND MAINTENANCE --------------------------------------(MEASURE CAT 1)

Let's start with operation and maintenance costs associated with <MEASURE CAT 1>.

OM2. Overall, did your annual O&M costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed? [Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to O&M measure cat 2]

98. Refused [Go to O&M measure cat 2]

OM3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual operation and maintenance costs?

[Record dollars, if respondent can't answer, GOTO OM5, Record (-96) if don't know and additional data provided below, (-97) if don't know and no additional data below, (-98) if refused; (-99) if not applicable)]

$__________

___ [Check here if used OM5]

-96 Don't know, additional data below → [Skip to OM5]

-97 Don't know, no additional data → [Skip to OM5]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

OM4 How did you estimate this amount?

[probe: what parts of the O&M costs were reduced/increased]

[Goto next O&M for Measure cat 2 if respondent answers OM4]

OM5 In which of the following categories did the installation of <MEASURE CAT 1> <increase / decrease> your O&M costs?

Column B. [Indicate whether it is an increase, decrease or did not change]

Column C. [Indicate how/why it changed]

Column D. [Indicate dollar value of change.]

[If labor, ask hours and loaded cost of labor, or hours and hourly rate. Be sure to put the hours and the value on the sheet, and indicate the total in column D on the correct line. Check the loaded value box if they told you fully loaded value.]

[If parts and supplies changed and they have trouble quantifying, try to determine what parts, the number of units, and average price. Be sure to put the value on the sheet, and indicate the total in column D on the correct line]

[If training costs changed, and they have trouble quantifying, try to determine hours of training and cost per hour. Also try to determine whether training costs impacted labor costs and if these changes are reflected above]

OM5 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
1 Internal labor			$_______ ☐ loaded value
2 External services/labor			
3 Parts & Supplies			
4 Training			
31. Fuel saved		Natural Gas No.2 Distillate No.4 Fuel Oil Propane Wood Kerosene	
99 Other			

OPERATIONS AND MAINTENANCE --------------------------------------(MEASURE CAT 2)

[If respondent does not have 2nd measure, skip to next NEI category]

Now let's talk about operation and maintenance costs associated with <MEASURE CAT 2>.

OM22. Overall, did your annual O&M costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed? [Circle all that apply]

1. Increase
2. Decrease
3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI category]

98. Refused [Go to next NEI category]

OM23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual operation and maintenance costs?

[Record dollars, if respondent can't answer, GOTO OM25, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used OM25]

-96 Don't know, additional data below → [Skip to OM25]

-97 Don't know, no additional data → [Skip to OM25]

-98 Refused → [Skip to next NEI category]

-99 Not applicable / Skipped → [Skip to next NEI category]

OM24 How did you estimate this amount?

[probe: what parts of the O&M costs were reduced/increased]

_____

_____

_____

[Goto next NEI category if respondent answers OM4]

OM25 In which of the following categories did the installation of <MEASURE CAT 2> <increase / decrease> your O&M costs?

OM25 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
1.Internal labor			$_______ ☐ loaded value
2. External services/labor			
3. Parts & Supplies			
4. Training			
31. Fuel saved		Natural Gas No.2 Distillate No.4 Fuel Oil Propane Wood Kerosene	
99. Other			

NEI Questions –Administration

Reread definition when you enter this section

This section refers to the company's time costs from the office people, like accounting.]

ADMINISTRATION---(MEASURE CAT 1)

Now let's talk about administration costs that changed because of the installation of <MEASURE CAT 1>?

LA2. Overall, did your annual administration costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97.DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Administration, measure cat 2]

98. Refused [Go to Administration, measure cat 2]

LA3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual administration costs?

[Record dollars, if respondent can't answer, GOTO LA5, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used LA5]

-96 Don't know, additional data below → [Skip to LA5]

-97 Don't know, no additional data → [Skip to LA5]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

LA4 How did you estimate this amount?

[probe: what parts of the administration costs were reduced/increased

Make sure no overlap with previous categories]

_____

_____

_____

[Goto Administration, Measure cat 2 if respondent answers LA4]

LA5 In which of the following categories did the installation of <MEASURE CAT 1> <increase / decrease> your administration costs?

Column B. [Indicate whether it is an increase, decrease or did not change]

Column C. [Indicate how/why it changed]

Column D. [Indicate dollar value of change.

If labor ask hours and loaded cost of labor, or hours and hourly rate. Be sure to put the hours and the value on the sheet, and indicate the total in column D on the correct line

If training costs changed, and they have trouble quantifying, try to determine hours of training and cost per hour. Also try to determine whether training costs impacted labor costs and if these changes are reflected above]

Make sure no overlap with previous categories.

LA5 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
1. Internal labor			$_______ ☐ loaded value
2. External services/labor			
4. Training			
99. Other			

ADMINISTRATION--(MEASURE CAT 2)

[If respondent does not have 2nd measure, skip to next NEI category]

Now let's talk about administration cost changes because of <MEASURE CAT 2>.

LA22. Overall, did your annual administration costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI category

98. Refused [Go to next NEI category]

LA23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual administration costs?

[Record dollars, if respondent can't answer, GOTO LA25, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used LA25]

-96 Don't know, additional data below → [Skip to LA25]

-97 Don't know, no additional data → [Skip to LA25]

-98 Refused → [Skip to Next NEI category]

-99 Not applicable / Skipped → [Skip to Next NEI category]

LA24 How did you estimate this amount?

[Probe: What parts of the administration costs were reduced/increased

Make sure no overlap with previous categories]

_____

_____

[Goto next NEI section if respondent answers LA24]

LA25 In which of the following categories did the installation of <MEASURE CAT 2> <increase / decrease> your administration costs?

Make sure no overlap with previous categories.

LA25 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
1. Internal labor			$_______ ☐ loaded value
2. External services/labor			
4. Training			
99. Other			

NEI Questions – Materials Handling

Reread this definition when you enter this section:

This section refers to the company's time and costs for people in the loading docks and warehouses.]

MATERIALS HANDLING--(MEASURE CAT 1)

Now let's talk about your materials handling costs because of <MEASURE CAT 1>

SH2. Overall, did your annual materials handling costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Materials Handling, measure cat 2]

98. Refused [Go to Materials Handling, measure cat 2]

SH3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual materials handling costs?

[Record dollars, if respondent can't answer, GOTO SH5, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used SH5]

-96 Don't know, additional data below → [Skip to SH5]

-97 Don't know, no additional data → [Skip to SH5]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

SH4 How did you estimate this amount?

[probe: what parts of the materials handling costs were reduced/increased

Make sure no overlap with previous categories]

_____

_____

_____

[Goto Materials Handling, Measure cat 2 if respondent answers SH4]

SH5 In which of the following categories did the installation of <MEASURE CAT 1> <increase / decrease> your materials handling costs? [

Column B. [Indicate whether it is an increase, decrease or did not change]

Column C. [Indicate how/why it changed]

Column D. [Indicate dollar value of change.

If supplies, verify not included in previous sections. If changed and they have trouble quantifying, try to determine what parts, the number of units, and average price. Be sure to put the value on the sheet, and indicate the total in column D on the correct line

If labor, verify not already included in previous sections, then ask hours and loaded cost of labor, or hours and hourly rate. Be sure to put the hours and the value on the sheet, and indicate the total in column D on the correct line]

Make sure no overlap with previous categories.

SH5 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
1.Internal labor			$_______ ☐ loaded value
2.External labor/ services			
99.Other			

MATERIALS HANDLING---(MEASURE CAT 2)

[If respondent has only 1 measure, go to next NEI section.]

Now lets talk about changes to your materials handling costs because of <MEASURE CAT 2>

SH22. Overall, did your annual materials handling costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all Probe: DK because some went up and some went down? If so, change to 3; else Go to next NEI Section]

98. Refused [Go to next NEI Section]

SH23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual materials handling costs?

[Record dollars, if respondent can't answer, GOTO SH25, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used SH25]

-96 Don't know, additional data below → [Skip to SH25]

-97 Don't know, no additional data → [Skip to SH25]

-98 Refused → [Skip to Next NEI section]

-99 Not applicable / Skipped → [Skip to Next NEI section]

SH24 How did you estimate this amount?

[probe: what parts of the materials handling costs were reduced/increased

Make sure no overlap with previous categories]

_____

_____

_____

[Goto next NEI section if respondent answers SH24]

SH25 In which of the following categories did the installation of <MEASURE CAT 2> <increase / decrease> your materials handling costs? [

Make sure no overlap with previous categories.

SH25 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
1.Internal labor			$_______ ☐ loaded value
2.External labor/ services			
99.Other			

NEI Questions –Materials Movement

Reread the definition when you enter this section:

This section refers to time and costs (gas, vehicles, pay) for truck drivers, both deliveries and pickups]

MATERIALS MOVEMENT-----------------------------(MEASURE CAT 1)

Now let's talk about changes to your materials movement costs because of <MEASURE CAT 1>.

TM2. Overall, did your annual materials movement costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Materials Movement, measure cat 2]

98. Refused [Go to Materials Movement, measure cat 2]

TM3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual materials movement costs?

[Record dollars, if respondent can't answer, GOTO TM5, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used TM5]

-96 Don't know, additional data below → [Skip to TM5]

-97 Don't know, no additional data → [Skip to TM5]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

TM4 How did you estimate this amount?

[probe: what parts of the materials movement costs were reduced/increased

Make sure no overlap with previous categories]

_____

_____

_____

[Goto Materials Movement, Measure cat 2 if respondent answers TM4]

TM5 In which of the following categories did the installation of <MEASURE CAT 1> <increase / decrease> your materials movement costs? [

Column B. [Indicate whether it is an increase, decrease or did not change]

Column C. [Indicate how/why it changed]

Column D. [Indicate dollar value of change.

If service/parts verify not included in previous sections. If costs changed and they have trouble quantifying, try to determine what parts, the number of units, and average price. Be sure to put the value on the sheet, and indicate the total in column D on the correct line

If fuel costs changed and they have trouble quantifying, try to determine what types of fuel (diesel), the quantities that changed (# gallons), and the average unit price ($/gallon).

If labor, verify not already included in previous sections, then ask hours and loaded cost of labor, or hours and hourly rate. Be sure to put the hours and the value on the sheet, and indicate the total in column D on the correct line]

Make sure no overlap with previous categories.

TM5 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
7. Fleet service & parts			
8. Fuel			
1. Internal labor			$_______ ☐ loaded value
2.External labor/ services			
99.Other			

MATERIALS MOVEMENT-----------------------------(MEASURE CAT 2)

[If respondent has only 1 measure, go to next NEI section.]

Now lets talk about changes to your materials movement costs because of <MEASURE CAT 2>

TM22. Overall, did your annual materials movement costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI Section]

98. Refused [Go to next NEI Section]

TM23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual materials movement costs?

[Record dollars, if respondent can't answer, GOTO TM25, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used TM25]

-96 Don’t know, additional data below → [Skip to TM25]

-97 Don’t know, no additional data → [Skip to TM25]

-98 Refused → [Skip to Next NEI section]

-99 Not applicable / Skipped → [Skip to Next NEI section]

TM24 How did you estimate this amount?

[probe: what parts of the materials movement costs were reduced/increased

Make sure no overlap with previous categories]

_____

_____

_____

[Goto next NEI section if respondent answers TM24]

TM25 In which of the following categories did the installation of <MEASURE CAT 2> <increase / decrease> your materials movement costs? [

Make sure no overlap with previous categories.

TM25 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
7. Fleet service & parts			
8. Fuel			
1. Internal labor			$________ ☐ loaded value
2.External labor/ services			
99.Other			

NEI Questions –Other Labor

Reread definition when you enter this section:

This section refers to the any other labor at the company not covered in O&M, Administration, Materials Handling or Materials Movement categories.]

OTHER LABOR---(MEASURE CAT 1)

Now let's talk about other labor costs that changed because of the installation of <MEASURE CAT 1>? By other, I'm referring to any labor we did not already talk about in previous categories.

OL2. Overall, did your other annual labor costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97.DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Other Labor, measure cat 2]

98. Refused [Go to Other Labor, measure cat 2]

OL3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your other annual labor costs?

[Record dollars, if respondent can't answer, GOTO OL5, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used OL5]

-96 Don't know, additional data below → [Skip to OL5]

-97 Don't know, no additional data → [Skip to OL5]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

OL4 How did you estimate this amount?

[probe: what parts of the labor costs were reduced/increased

Make sure no overlap with previous categories]

_____

_____

_____

[Goto Other Labor measure cat 2 if respondent answers OL4]

OL5 In which of the following categories did the installation of <MEASURE CAT 1> <increase / decrease> your other labor costs?

Column B. [Indicate whether it is an increase, decrease or did not change]

Column C. [Indicate how/why it changed]

Column D. [Indicate dollar value of change.

If labor ask hours and loaded cost of labor, or hours and hourly rate. Be sure to put the hours and the value on the sheet, and indicate the total in column D on the correct line

If training costs changed, and they have trouble quantifying, try to determine hours of training and cost per hour. Also try to determine whether training costs impacted labor costs and if these changes are reflected above]

Make sure no overlap with previous categories.

OL5 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
1. Internal labor			$_______ ☐ loaded value
2. External services/labor			
4. Training			
99. Other			

OTHER LABOR---(MEASURE CAT 2)

[If respondent does not have 2nd measure, skip to next NEI category]

Now let's talk about other labor cost changes because of <MEASURE CAT 2>.

OL22. Overall, did your other annual labor costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI category

98. Refused [Go to next NEI category]

OL23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your other annual labor costs?

[Record dollars, if respondent can't answer, GOTO OL25, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used OL25]

-96 Don’t know, additional data below → [Skip to OL25]

-97 Don’t know, no additional data → [Skip to OL25]

-98 Refused → [Skip to Next NEI section]

-99 Not applicable / Skipped → [Skip to Next NEI section]

OL24 How did you estimate this amount?

[probe: what parts of the other costs were reduced/increased

Make sure no overlap with previous categories]

_____

_____

_____

[Goto next NEI section if respondent answers OL24]

OL25 In which of the following categories did the installation of <MEASURE CAT 2> <increase / decrease> your other labor costs?

Make sure no overlap with previous categories.

OL25 Category	B **1 Increase** **2 Decrease** **3 No change**	C **How so**	D **$ Value**
1. Internal labor			$_______ ☐ loaded value
2. External services/labor			
4. Training			
99. Other			

NEI Questions –Water Usage and Wastewater

Reread definition when you enter this section:

This section refers to the company's costs for water usage and wastewater.]

WATER USAGE---(MEASURE CAT 1)

Now let's talk about changes to your water usage and wastewater costs because of <MEASURE CAT 1>.

FW2. Overall, did your annual water usage and wastewater costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Water Usage, measure cat 2]

98. Refused [Go to Water Usage, measure cat 2]

FW3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual water usage and wastewater costs?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$__________

___ [Check here if bracketed]

-96 Don't know, additional data below → [Skip to Measure cat 2]

-97 Don't know, no additional data → [Skip to Measure cat 2]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

FW4 How did you estimate this amount?

[probe: what parts of the water usage and wastewater costs were reduced/increased

If respondent has difficulty estimating amount, ask for gallons of water change and average price per gallon

Make sure no overlap with previous categories.

FW5 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
32. Water usage costs			
33. Water gallons			
34. Wastewater			

WATER USAGE---(MEASURE CAT 2)

[If respondent does not have 2nd measure, skip to next NEI category]

Now let's talk about changes to your water usage and wastewater costs because of <MEASURE CAT 2>.

FW22. Overall, did your annual water usage and wastewater costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI category]

98. Refused [Go to next NEI category]

FW23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual water usage and wastewater costs?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$_________

___ [Check here if bracketed]

-96 Don't know, additional data below → [Skip to Next NEI Section]

-97 Don't know, no additional data → [Skip to Next NEI Section]

-98 Refused → [Skip to Next NEI Section]

-99 Not applicable / Skipped → [Skip to Next NEI Section]

FW24 How did you estimate this amount?

[probe: what parts of the water usage and wastewater costs were reduced/increased

If respondent has difficulty estimating amount, ask for gallons of water change and average price per gallon

Make sure no overlap with previous categories.]

FW25 Category	**B** **1 Increase** **2 Decrease** **3 No change**	**C** **How so**	**D** **$ Value**
32. Water usage costs			
33. Water gallons			
34. Wastewater			

NEI Questions – Product Spoilage

Reread definition when you enter this section:

This section refers to the company's costs for lost or damaged products, including production defects.]

PRODUCT SPOILAGE -- (MEASURE CAT 1)

Now let's talk about your company's changes to costs for product spoilage because of <MEASURE CAT 1>

SD2. Overall, did your annual product spoilage costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Product Spoilage, measure cat 2]

98. Refused [Go to Product Spoilage, measure cat 2]

SD3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual product spoilage costs?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$_________

___ [Check here if bracketed]

-96 Don't know, additional data below → [Skip to Measure cat 2]

-97 Don’t know, no additional data → [Skip to Measure cat 2]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

SD4 How did you estimate this amount?

[probe: what parts of the product spoilage costs were reduced/increased

Make sure no overlap with previous categories.]

PRODUCT SPOILAGE--- (MEASURE CAT 2)

[If respondent does not have 2nd measure, skip to next NEI category]

Now let’s talk about product spoilage cost changes because of <MEASURE CAT 2>.

SD22. Overall, did your annual product spoilage costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don’t know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI category]

98. Refused [Go to next NEI category]

SD23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual product spoilage costs?

[Record dollars, if respondent can’t answer, bracket starting at $100,000]

$_________

___ [Check here if bracketed]

-96 Don’t know, additional data below → [Skip to Next NEI Section]

-97 Don’t know, no additional data → [Skip to Next NEI Section]

-98 Refused → [Skip to Next NEI Section]

-99 Not applicable / Skipped → [Skip to Next NEI Section]

SD24 How did you estimate this amount?

[probe: what parts of the product spoilage costs were reduced/increased

Make sure no overlap with previous categories.]

NEI Questions – Waste Disposal

[This section refers to any costs the company incurs from disposal of all solid and gaseous wastes (ie. Pollution).]

WASTE DISPOSAL---(MEASURE CAT 1)

Now let's talk about changes to your waste disposal costs because of <MEASURE CAT 1>

SW2. Overall, did your annual waste disposal costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all Probe: DK because some went up and some went down? If so, change to 3; else go to waste disposal, measure cat 2]

98. Refused [Go to waste disposal, measure cat 2]

SW3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual waste disposal costs?

[Record dollars, if respondent can't answer, GOTO SW5, then come back and fill in the total here and check the space under the estimate]

$__________

___ [Check here if used SW5]

-96 Don't know, additional data below → [Skip to SW5]

-97 Don't know, no additional data → [Skip to SW5]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

SW4 How did you estimate this amount?

[probe: what parts of the waste disposal costs were reduced/increased

Make sure no overlap with previous categories]?

[Goto next Waste Disposal, Measure cat 2 if respondent answers SW4]

SW5 In which of the following categories did the installation of <MEASURE CAT 1> <increase / decrease> your waste disposal costs? [

Column B. [Indicate whether it is an increase, decrease or did not change]

Column C. [Indicate how/why it changed]

Column D. [Indicate dollar value of change.

If waste materials have changed and they have trouble quantifying, try to determine what materials changed, whether they generated more or less of that type of waste materials, the number of units change, and average price per unit. Be sure to put the value on the sheet, and indicate the total in column D on the correct line

If waste handling costs include labor, verify not already included in previous sections, then ask hours and loaded cost of labor, or hours and hourly rate. Be sure to put the hours and the value on the sheet, and indicate the total in column D on the correct line

If they have trouble quantifying permit costs, try to determine what waste materials they need permits for and the average cost of the permit]

Make sure no overlap with previous categories.

SW5 Category	B 1 Increase 2 Decrease 3 No change	C How so	D $ Value
9. Waste materials			
10. Waste handling			
11. Permits			
99. Other			

WASTE DISPOSAL---(MEASURE CAT 2)

[If respondent has only 1 measure, go to next NEI section.]

Now lets talk about changes to your waste disposal costs because of <MEASURE CAT 2>

SW22. Overall, did your annual waste disposal costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all Probe: DK because some went up and some went down? If so, change to 3; else [Go to next NEI Section]

98. Refused [Go to next NEI Section]

SW23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual waste disposal costs?

[Record dollars, if respondent can't answer, GOTO SW25, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used SW25]

-96 Don't know, additional data below → [Skip to SW25]

-97 Don't know, no additional data → [Skip to SW25]

-98 Refused → [Skip to Next NEI Section]

-99 Not applicable / Skipped → [Skip to Next NEI Section]

SW24 How did you estimate this amount?

[probe: what parts of the waste disposal costs were reduced/increased

Make sure no overlap with previous categories]?

[Goto next NEI section if respondent answers SW24]

SW25 In which of the following categories did the installation of <MEASURE CAT 2> <increase / decrease> your waste disposal costs?

Make sure no overlap with previous categories.

SW25 Category	B 1 Increase 2 Decrease 3 No change	C How so	D $ Value
9. Waste materials			
10. Waste handling			
11. Permits			
99. Other			

NEI Questions –Fees

This section refers to the company's fees including insurance, inspections, permits and legal fees.]

FEES ---------------------------------- (MEASURE CAT 1)

Now let's talk about how <MEASURE CAT 1> changed your company's fees.

IL2. Overall, did your fees increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Fees, measure cat 2]

98. Refused [Go to Fees, measure cat 2]

IL3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual fees?

[Record dollars, if respondent can't answer, GOTO IL5, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used IL5]

-96 Don't know, additional data below → [Skip to IL5]

-97 Don't know, no additional data → [Skip to IL5]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

IL4 How did you estimate this amount?

[probe: what parts of the fees were reduced/increased

If respondent has difficulty estimating amount, ask them to estimate insurance, inspections, and legal fees separately.

Make sure no overlap with previous categories]

[Goto Fees, Measure cat 2 if respondent answers IL4]

IL5 In which of the following categories did the installation of <MEASURE CAT 1> <increase / decrease> your company's annual fees?

Make sure no overlap with previous categories.

IL5 Category	B 1 Increase 2 Decrease 3 No change	C How so	D $ Value
21. Insurance			
22. Licensing			
23. Inspections			
24. Legal fees			
99. Other			

FEES ---------------------------------- (MEASURE CAT 2)

[If respondent does not have 2nd measure, skip to next NEI category]

Now let's talk about how <MEASURE CAT 2> changed your company's fees.

IL22. Overall, did your annual fees increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI category]

98. Refused [Go to next NEI category]

IL23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual fees?

[Record dollars, if respondent can't answer, GOTO IL25, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used IL25]

-96 Don't know, additional data below → [Skip to IL25]

-97 Don't know, no additional data → [Skip to IL25]

-98 Refused → [Skip to Next NEI Section]

-99 Not applicable / Skipped → [Skip to Next NEI Section]

IL24 How did you estimate this amount?

[probe: what parts of the fees were reduced/increased

If respondent has difficulty estimating amount, ask them to estimate insurance, inspections, permits and legal fees separately

Make sure no overlap with previous categories]

[Goto next NEI section if respondent answers IL24]

IL25 In which of the following categories did the installation of <MEASURE CAT 2> <increase / decrease> your company's annual fees?

Make sure no overlap with previous categories.

IL25 Category	B 1 Increase 2 Decrease 3 No change	C How so	D $ Value
21. Insurance			
22. Licensing			
23. Inspections			
24. Legal fees			
99. Other			

NEI Questions – Other costs

[This section refers to any other costs not yet covered in the survey.]

OTHER COSTS-- (MEASURE CAT 1)

Now let's talk about any other non-energy related costs that changed because of <MEASURE CAT 1>.

OC2. Overall, did these other costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all Probe: DK because some went up and some went down? If so, change to 3; else go to other costs, measure cat 2]

98. Refused [Go to other costs, measure cat 2]

OC3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual other costs?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$__________

___ [Check here if bracketed]

-96 Don't know, additional data below → [Skip to Measure cat 2]

-97 Don't know, no additional data → [Skip to Measure cat 2]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

OC4 How did you estimate this amount?

Make sure no overlap with previous categories.

OTHER COSTS-- (MEASURE CAT 2)

[If respondent does not have 2nd measure, skip to next NEI category]

Now let's talk about how your other costs changed because of <MEASURE CAT 2>.

OC22. Overall, did these other costs increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all Probe: DK because some went up and some went down? If so, change to 3; else [Go to next NEI category]

98. Refused [Go to next NEI category]

OC23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual other costs?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$_________

___ [Check here if bracketed]

-96 Don't know, additional data below → [Skip to Next NEI section]

-97 Don't know, no additional data → [Skip to Next NEI section

-98 Refused → [Skip to Next NEI section]

-99 Not applicable / Skipped → [Skip to Next NEI section]

OC24 How did you estimate this amount?

Make sure no overlap with previous categories.

NEI Questions – Sales

[This section refers to any sales changes the company experienced due to installing the measures.]

SALES---(MEASURE CAT 1)

Now let's talk about any changes to your company's sales because of <MEASURE1>

PR2. Overall, did your annual sales levels increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Sales, measure cat 2]

98. Refused [Go to Sales, measure cat 2]

PR3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual sales levels?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$_________

___ [Check here if bracketed]

-96 Don't know, additional data below → [Skip to Measure cat 2]

-97 Don't know, no additional data → [Skip to Measure cat 2]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

PR4 How did you estimate this amount?

[Probe: what parts of the sales were reduced/increased

Make sure no overlap with previous categories.]

SALES --(MEASURE CAT 2)

[If respondent has only 1 measure, go to next NEI section.]

Now let's talk about any changes to your company's sales because of <MEASURE2>

PR22. Overall, did your annual sales levels increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI section]

98. Refused [Go to next NEI section]

PR23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual sales levels?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$_________

___ [Check here if bracketed]

-96 Don't know, additional data below → [Skip to Next NEI Section]

-97 Don't know, no additional data → [Skip to Next NEI Section]

-98 Refused → [Skip to Next NEI Section]

-99 Not applicable / Skipped → [Skip to Next NEI Section]

PR24 How did you estimate this amount?

[Probe: what parts of the production or revenues were reduced/increased

Make sure no overlap with previous categories]?

_____

_____

_____

NEI Questions – Rent Revenue

This section refers to any rent revenue changes the company experienced due to installing the measures.]

RENT REVENUE---(MEASURE CAT 1)

Now let's talk about any rent revenue changes your company experienced because of <MEASURE1>

RR2. Overall, did your annual rent revenues increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to Rent Revenues, measure cat 2]

98. Refused [Go to Rent Revenues, measure cat 2]

RR3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual rent revenues?

[Record dollars, if respondent can't answer, GOTO RR5, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used RR5]

-96 Don't know, additional data below → [Skip to RR5]

-97 Don't know, no additional data → [Skip to RR5]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

RR4 How did you estimate this amount?

Make sure no overlap with previous categories

[Goto Rent Revenues, Measure cat 2 if respondent answers RR4]

RR5 In which of the following categories did the installation of <MEASURE CAT 1> <increase / decrease> your rent revenues? [

Column B. [Indicate whether it is an increase, decrease or did not change]

Column C. [Indicate how/why it changed]

Column D. [Indicate dollar value of change.]

Make sure no overlap with previous categories

RR5 Category	B 1 Increase 2 Decrease 3 No change	C How so	D $ Value
13. # units produced			
14. Per unit production costs			
15. Revenue per unit			

RENT REVENUE --(MEASURE CAT 2)

[If respondent has only 1 measure, go to next NEI section.]

Now let's talk about any rent revenue changes your company experienced because of <MEASURE2>

RR22. Overall, did your annual rent revenues increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI section]

98. Refused [Go to next NEI section]

RR23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual rent revenues?

[Record dollars, if respondent can't answer, GOTO RR25, then come back and fill in the total here and check the space under the estimate]

$_________

___ [Check here if used RR25]

-96 Don't know, additional data below → [Skip to RR25]

-97 Don't know, no additional data → [Skip to RR25]

-98 Refused → [Skip to Next NEI Section]

-99 Not applicable / Skipped → [Skip to Next NEI Section]

RR24 How did you estimate this amount?

Make sure no overlap with previous categories

[Goto next NEI section if respondent answers RR24]

RR25 In which of the following categories did the installation of <MEASURE CAT 2> <increase / decrease> your rent revenues? [

Column B. [Indicate whether it is an increase, decrease or did not change]

Column C. [Indicate how/why it changed]

Column D. [Indicate dollar value of change.]

Make sure no overlap with previous categories

RR25 Category	B 1 Increase 2 Decrease 3 No change	C How so	D $ Value
13. # units produced			
14. Per unit production costs			
15. Revenue per unit			

NEI Questions – Other revenues

[This section refers to any other revenues not yet covered in the survey.]

OTHER REVENUES-- (MEASURE CAT 1)

Now let's talk about any other non-energy related revenues that changed because of <MEASURE CAT 1>.

OR2. Overall, did these other revenues increase or decrease because of any of the *high efficiency* <MEASURE CAT 1> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to other revenues, measure cat 2]

98. Refused [Go to other revenues, measure cat 2]

OR3. By how much did the installation of <MEASURE CAT 1> <increase / decrease> your annual other revenues?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$_________

___ [Check here if bracketed]

-96 Don't know, additional data below → [Skip to Measure cat 2]

-97 Don't know, no additional data → [Skip to Measure cat 2]

-98 Refused → [Skip to Measure cat 2]

-99 Not applicable / Skipped → [Skip to Measure cat 2]

OR4 How did you estimate this amount?

Make sure no overlap with previous categories

OTHER REVENUES-- (MEASURE CAT 2)

[If respondent does not have 2nd measure, skip to next NEI category]

Now let's talk about any other non-energy related revenues that changed because of <MEASURE CAT 2>.

OR22. Overall, did these other revenues increase or decrease because of any of the *high efficiency* <MEASURE CAT 2> you installed?

[Circle all that apply]

1. Increase

2. Decrease

3. Some went up, some went down – don't know overall

97. DK at all [Probe: DK because some went up and some went down? If so, change to 3; else go to next NEI category]

98. Refused [Go to next NEI category]

OR23. By how much did the installation of <MEASURE CAT 2> <increase / decrease> your annual other revenues?

[Record dollars, if respondent can't answer, bracket starting at $100,000]

$_________

___ [Check here if used bracket]

-96 Don't know, additional data below → [Skip to Next NEI Section]

-97 Don't know, no additional data → [Skip to Next NEI Section]

-98 Refused → [Skip to Next NEI Section]

-99 Not applicable / Skipped → [Skip to Next NEI Section]

OR24 How did you estimate this amount? Make sure no overlap with previous categories

Spillover

This section is to ask them about any additional projects they did since participating in the program in 2010. The interviewer will determine if we already know about these projects, and if not, whether they are "like" or "unlike" projects.

When you ask about additional projects, you need to confirm that the project did not involve one of the measures you already talked about with the respondent during the NEI section.

If it is the measures we already know about, skip the rest of these questions for that measure and go to the next measure.

Get detailed information based on the measure type:

Lighting – types (T12, Standard T8, High performance T8, T5, HID, Other) and number of fixtures installed

HVAC – type (packaged AC, rooftop AC, split AC, furnace, boiler, heat pump, geothermal, Other), capacity (tons or MBTU/hr), and SEER or efficiency rating. If something like ducts or fans where capacity and SEER not applicable, get quantity

Motors – number, horsepower, and efficiency rating

Compressed Air – description, number, and size (horsepower or cubic feet/minute) of what was installed

Refrigeration – Number, size (tons or MBTU/hr), and efficiency of units

Building Envelope – square feet heated and cooled space impacted by measure.

Water – Number and description of what was installed. If a water heater, the efficiency rating, MBTU/hr

Please pre-populate the list of additional measures that we have on file for the customer site. You will use this to double-check against any measures the participant discusses with you beyond the two measures that you discussed in the NEI section.

Known Measures:

MEASURE 1:________________________

MEASURE 2:________________________

MEASURE 3:________________________

MEASURE 4: _______________________

MEASURE 5:________________________

MEASURE 6:________________________

MEASURE 7:________________________

MEASURE 8:________________________

Please record any additional measures as necessary.]

S1. . Now I have some questions to ask you about any projects involving energy using equipment that you might have done since the ones we just talked about.

Since participating in <PROGRAM> in 2010, has your company purchased, or installed any energy efficiency equipment in the following categories?

Did you install any energy efficient equipment since 2010	
Lighting	
HVAC	
Motors	
Compressed Air	
Refrigeration	
Building Envelope	
Water	
Other	

[If all No, then end interview]

[If DK, probe for contact who might know]

[For any measure category they say yes to, get detailed information about those measures. Record on next page.]

S2. What did you install?

Equipment 1

Location:____

Record type: ____

Same Type as a known measure?: _______________________

Record quantity: ____

Record size or capacity: ____

Efficiency level (Energy Star?):________________________________

Efficiency level *relative to similar known measure?*

____Same ____Equipment 1 is Higher _____Equipment 1 is Lower

[Probe for "anything else" until they say nothing else. Add additional Equipments as necessary.]

Equipment 2

Location:____

Record type: ____

Same Type as a known measure?: _______________________

Record quantity: ____

Record size or capacity: ____

Efficiency level (Energy Star?):________________________________

Efficiency level *relative to similar known measure?*

____Same ____Equipment 2 is Higher _____Equipment 2 is Lower

Equipment 3

Location:____

Record type: ____

Same Type as a known measure?: _______________________

Record quantity: ____

Record size or capacity: ____

Efficiency level (Energy Star?):________________________________

Efficiency level *relative to similar known measure?*

____Same ____Equipment 3 is Higher _____Equipment 3 is Lower

Equipment 4

Location:____

Record type: ____

Same Type as a known measure?: _______________________

Record quantity: ____

Record size or capacity: ____

Efficiency level (Energy Star?):________________________________

Efficiency level *relative to similar known measure?*

____Same ____Equipment 4 is Higher _____Equipment 4 is Lower

Equipment 5

Location:____

Record type: ____

Same Type as a known measure?: _______________________

Record quantity: ____

Record size or capacity: ____

Efficiency level (Energy Star?):________________________________

Efficiency level *relative to similar known measure?*

____Same ____Equipment 5 is Higher _____Equipment 5 is Lower

[Ask S3 and S4 if the new equipment is the same type as one of the measures we asked the NEI questions for

Else GOTO S5]

S3. Did you install more, less or the same amount of <new equipment> as <equipment we asked NEI questions about>?

[PROBE: We're looking for a percent compared to the amount installed through the program. For example, was it about one- fourth of what you installed through the program, one-half of what you installed through the program, the same (100%) amount as you installed through the program, twice as much as what you installed through the program (200%) or some other amount?

Units of quantity depend on measure type:

Lighting → # of fixtures

HVAC → Tons or MBTU/hr (Millions of BTU per hour)

Refrigeration → Tons

Motors → Total horsepower

Compressed Air → Horsepower or CFM (Cubic feet/minute)

Building Envelope → Total enclosed square feet affected

Water → MBTU/hr (Millions BTU per hour) or varies – confirm unit with respondent

Process → Varies – get units from respondent

Comprehensive → Varies – get units from respondent

S3	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5
1 More (%____) 2 Less (%____) 3 Same (→ S5) 97 (DK) 98 (Ref)					

S4. To confirm, you installed an additional <percentage from S5> of <new equipment> as you got incentives for through the program?

1 Yes

2 No [correct S3]

S5. Did you receive any incentives from energy efficiency programs for this piece of equipment?

S5	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5
1 Yes[Which ones? → S7] 2 No [→ S6] 97 (DK) [→ S7] 98 (Ref)					

S6. Why not?

S6	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5
Record verbatim, then post-code					

1 (The equipment would not qualify)
2 (Too much paperwork)
3 (Cost savings not worth the effort of applying)
4 (Takes too long for approval)
5 (Vendor does not participate in program)
6 (Outside <PA>'s service territory)
7 (No time - needed equipment immediately)
8 (Thought the program ended)
9 (Didn't know the equipment qualified under another program)
10 (Just didn't think of it)
11 (Unable to get rebate--unsure why)
12 (Other) (SPECIFY)
97 (DK)

S7. Did your experience with the projects we discussed earlier [the NEI projects] influence your decision to install any of this equipment?

S7	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5

[If they say yes, get the level of influence of their experience with the NEI projects. Use 0 to 10 scale where 0 = “no influence at all” and 10 = “a great deal of influence”]

S8. Did your participation in any past energy efficiency programs offered by <PA> influence your decision to install any of this equipment?

S8	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5
[Get 0 to 10 influence ranking] 97 (DK) 98 (Ref)					

[If they say yes, get the level of influence of their experience with the NEI projects. Use 0 to 10 scale where 0 = “no influence at all” and 10 = “a great deal of influence”]

S9. Did a contractor, engineer, or designer who helped you with a previous energy efficiency project that influence your decision to install this equipment?

S9	Equipment 1	Equipment 2	Equipment 3	Equipment 4	Equipment 5
[Get 0 to 10 influence ranking] 97 (DK) 98 (Ref)					

[If they say yes, get the level of influence of their experience with the NEI projects. Use 0 to 10 scale where 0 = “no influence at all” and 10 = “a great deal of influence”]

[GOTO next Spillover Equipment]

Thank you. That’s all the questions I have for you today. If necessary, would it be ok for me to call you back to clarify my notes? Once again, thank you for your responses. Have a good day.

Appendix E. CUSTOM MEASURE INTERVIEW GUIDE

MA NEI Custom Interview

Call ID:___________

Contact________________________________

Company: ________________________________

Clean_Phone: ________________________________

Address: ________________________________

Alternate phone: ______________________________

Reporting Category 1: ___________________ Measure ID1:____________________

Reporting Category 2 ___________________ Measure ID2:____________________

PA Name: __ Program Name:___ _________

Participation Date: ____

Call #	Date	Time	Notes (include message left, best time to call, best way to contact, and whether survey was completed)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Final Disposition: O complete O refused O no answer O mid-terminate
O other (specify____)

Interview Length:________

Purpose of the Interview

1. Determine whether measures resulted in non-energy impacts (NEIs –"any positive or negative effect beyond energy savings that are attributable to energy efficiency programs")

2. Identify sources of NEIs that resulted from the installed measures

3. Obtain estimates of non-energy impacts (NEI)

a. Seek monetized non-energy benefits or costs

b. If respondents cannot monetize NEIs, guide respondents through relevant probes to obtain the necessary information for imputing monetized estimates of NEI;

4. Obtain measures of spillover – Participant spillover is energy savings resulting from program influenced installation of energy efficiency measures that did not receive program incentives. We will obtain estimates of both like and un-like spillover.

a. Like spillover – Energy savings resulting from program influenced installation of energy-efficient equipment of the same type (i.e. the same measure, capacity, and efficiency level)

b. Unlike spillover – Energy savings resulting from program influenced installation of energy-efficient equipment of the a different type (i.e. different measure, capacity, or efficiency level)

Introduction and Screening

[Get <<CONTACT>> on the phone]

Hello, my name is __ and I am calling from KEMA Consulting on behalf of <<PA NAME>> and <<PROGRAM>>

I'm calling to get some feedback on how the energy efficiency improvements you made through <<PROGRAM>> have affected your organization's costs and revenues. Someone else from KEMA called you a few days ago to set up this interview.

Are you still the person at <<COMPANY>> most familiar with the outcomes of your organization's participation and experience with the <<PROGRAM>> program?

[If necessary] Last Spring, someone from the evaluation team spoke you about your participation in the <<PA NAME>> <<PROGRAM>> program around <<PARTICIPATION DATE>>.

[If "No"] Who is the right person to talk to? [Get name and contact information. Attempt to reach]

[Once correct person on phone]: All of your answers are confidential and will only be reported in aggregate.

[If asked]: You can verify the legitimacy of this research by calling ____________ at ____________

[If asked]: KEMA is an independent contractor hired to do this research.

[If different contact, record information below]

Name:__ ____

Phone: ___________________________; Alt phone:________________________________

Address: ____

About the Respondent

Let's start by getting a little information about your organization and you. These questions help us put the rest of your answers in context.

F1. What is the major economic activity at <<ADDRESS>>?

F2. How many full-time equivalent employees work at <<ADDRESS>>? [Bracket if don't know. Start at 100 employees and go up or down]

F3. What is the total square footage of conditioned space at <<ADDRESS>>? [Bracket if don't know. Start at 10,000 square feet and go up or down.]

AR1. What is your job title?

AR2. What are your responsibilities?

AR3. How long have you done that?

Equipment Verification

My records show that you have installed the following measures through <<PROGRAM>>:

MEASURE 1._______________________

MEASURE 2:________________________

MEASURE 3:________________________

MEASURE 4: _______________________

MEASURE 5:________________________

MEASURE 6:________________________

MEASURE 7:_______________________

MEASURE 8:_______________________

[add additional measures as necessary]

[Ask questions below and fill in table for each measure]

Question	Measure 1	Measure 2	Measure 3	Measure 4	Measure 5	Measure 6	Measure 7	Measure 8
EV2								
EV3								
EV4								
EV5								
EV6								

EV2. Is this equipment still installed?

1 Yes [Go to EV5]

2 No [Go to EV3]

97 Don't know [Ask for alternate contact who could answer]

98 Refused [Ask for alternate contact who could answer]

EV3. Why was it removed?

EV4. What, if anything, did you install in its place? [Skip to EV7.]

EV5. Is this equipment still operational?

1 Yes [Go to EV7]

2 No [Go to EV6]

97 Don't know [Ask for alternate contact who could answer]

98 Refused [Ask for alternate contact who could answer]

EV6. Why not?

[Continue survey with any measures still installed.

If all measures no longer installed, ask NEI sections if reason for removal might be relevant to NEI. For example, "It increased O&M costs too much." If reason for removal not relevant to NEI, end interview.]t

EV7. Could you tell me a little more about this project? I only have a brief description in my records, so I'm trying to get a little more detail about it.

[Probes: different pieces; electric vs. gas; connected to any other equipment]

[Ask free-ridership section only if <analysis> ≠ 1 for a measure in a reporting category.

If all measures have <analysis> = 1, skip to EV8]

Free-Ridership

FR1. Next, I have some questions about the effect the incentives from the <PA>and MASS Save program had on your decision to purchase a <MEASURE>.

Without the program, would you say the likelihood of purchasing the <MEASURE> was…

[READ UNBRACKETED OPTIONS]

1	**Very likely**	
2	**Somewhat likely**	
3	**Not very likely**	
4	**Or very unlikely**	
97	[Don't know]	
98	[Refused]	

TIMING

FR2a. What effect, if any, did program incentives have on your decision to purchase the <MEASURE> when you did. I'm referring to your decision to purchase any <MEASURE>, not just an energy efficient model.

Without the program, would you have purchased them at the same time, earlier, later, or never?

1	[at the Same time]	FR2c
2	[Earlier]	FR2c
3	[Later]	FR2b
4	[Never]	FR2c
97	[Don't know]	FR2c

Appendix F. DETAILED DISPOSITIONS

F-1 Dispositions By Strata – Prescriptive Electric

Strata	Sampling Measure Group	Size	Frame	Target	Sample Completes	Status
1	Compressed Air	All	6	4	2	Exhausted
2	Compressed Air	Small	5	3	1	Exhausted
3	Compressed Air	Medium	4	2	2	Exhausted
4	Compressed Air	Large	1	1.328265	1	Exhausted
5	HVAC	Small	15	7	9	Exhausted
6	HVAC	Medium	4	6	3	Exhausted
7	HVAC	Large	1	1	0	Exhausted
8	HVAC	Small	29	13	14	Exhausted
9	HVAC	Medium	12	13	1	Exhausted
10	HVAC	Large	1	1.299588	0	Exhausted
11	Lighting	Very Small	135	12	16	Available
12	Lighting	Small	57	12	12	Available
13	Lighting	Medium	49	12	13	Available
14	Lighting	Large	27	12	4	Exhausted
15	Lighting	Very Large	18	12	9	Exhausted
16	Lighting	Very Small	277	14	58	Available
17	Lighting	Small	108	14	28	Available
18	Lighting	Medium	66	14	16	Available
19	Lighting	Large	26	14	6	Exhausted
20	Lighting	Very Large	14	14	1	Exhausted
21	Motors and Drives	Very Small	29	8	14	Exhausted
22	Motors and Drives	Small	11	8	5	Exhausted
23	Motors and Drives	Medium	8	8	8	Exhausted
24	Motors and Drives	Large	6	7	0	Exhausted
25	Motors and Drives	Very Large	5	8.14105	2	Exhausted
26	Motors and Drives	Very Small	28	5	10	Exhausted
27	Motors and Drives	Small	14	5	6	Exhausted
28	Motors and Drives	Medium	6	5	3	Exhausted
29	Motors and Drives	Large	3	4	0	Exhausted
30	Motors and Drives	Very Large	14	24.70786	2	Exhausted
31	Process	All	2	2	1	Exhausted
32	Refrigeration	Small	7	4	1	Exhausted
33	Refrigeration	Large	3	3	0	Exhausted
34	Refrigeration	Small	30	11	18	Exhausted
35	Refrigeration	Medium	13	11	6	Exhausted
36	Refrigeration	Large	6	10	5	Exhausted
37	Building Envelope	All	1	1	0	Exhausted
38	Comprehensive	Small	52	4	5	Available
39	Comprehensive	Large	17	3	0	Exhausted
40	Comprehensive	Small	97	5	19	Available
41	Comprehensive	Large	41	4	2	Exhausted
Total			**1248**	**322.4768**	**303**	

F-2 Dispositions By Strata – Prescriptive Gas

Strata	Sampling Measure Group	Size	Frame	Target	Sample Completes	Status
1	Building Envelope	All	3	2	2	Exhausted
2	HVAC	Small	28	10	22	Exhausted
3	HVAC	Medium	6	10	4	Exhausted
4	HVAC	Large	4	9	0	Exhausted
5	HVAC	Very Small	45	12	10	Exhausted
6	HVAC	Small	18	11	10	Exhausted
7	HVAC	Large	5	11	2	Exhausted
8	HVAC	Very Large	3	12.58462	1	Exhausted
9	Water Heater	Small	17	10	14	Exhausted
10	Water Heater	Large	7	9	6	Exhausted
11	Water Heater	Very Small	42	12	16	Exhausted
12	Water Heater	Small	20	11	6	Exhausted
13	Water Heater	Medium	11	11	3	Exhausted
14	Water Heater	Large	6	11	2	Exhausted
15	Water Heater	Very Large	1	6.3	0	Exhausted
16	Process	All	1	1	0	Exhausted
Total			**217**	**148.8846**	**98**	

F-3 Dispositions By Strata – Custom Electric

Strata	Sampling Measure Group	Size	Frame	Target	Sample Completes	Status
1	Lighting	All	1	1	1	Exhausted
2	Lighting	All	1	1	0	Exhausted
3	Motors and Drives	All	2	1	0	Exhausted
4	Lighting	All	1	1	0	Exhausted
5	Building Envelope	All	5	3	4	Exhausted
6	CHP/Cogen	Small	6	3	4	Exhausted
7	CHP/Cogen	Medium	3	3	1	Exhausted
8	CHP/Cogen	Large	2	2	1	Exhausted
9	Compressed Air	Small	7	3	3	Exhausted
10	Compressed Air	Medium	2	2	1	Exhausted
11	Compressed Air	Large	3	3	0	Exhausted
12	HVAC	Very Small	18	3	3	Available
13	HVAC	Small	7	3	1	Exhausted
14	HVAC	Medium	5	3	2	Exhausted
15	HVAC	Large	5	3	1	Exhausted
16	HVAC	Very Large	7	7	3	Exhausted
17	Lighting	Very Small	58	4	9	Available
18	Lighting	Small	19	4	11	Available
19	Lighting	Medium	10	4	7	Exhausted
20	Lighting	Large	7	4	3	Exhausted
21	Lighting	Very Large	3	3	0	Exhausted
22	Motors and Drives	Very Small	27	6	14	Available
23	Motors and Drives	Small	14	6	9	Available
24	Motors and Drives	Small to Medium	13	5	7	Exhausted
25	Motors and Drives	Medium to Large	9	5	5	Exhausted
26	Motors and Drives	Large	5	5	3	Exhausted
27	Motors and Drives	Very Large	4	4	1	Exhausted
28	Process	Small	8	4	3	Exhausted
29	Process	Medium	4	3	1	Exhausted
30	Process	Large	3	3	0	Exhausted
31	Refrigeration	Very Small	16	4	2	Exhausted
32	Refrigeration	Small	3	3	0	Exhausted
33	Refrigeration	Medium	3	3	0	Exhausted
34	Refrigeration	Large	3	3	1	Exhausted
35	Refrigeration	Very Large	3	3	3	Exhausted
36	Other	Small	16	4	7	Exhausted
37	Other	Medium	5	4	1	Exhausted
38	Other	Large	2	2	0	Exhausted
39	CHP/Cogen	All	4	3	0	Exhausted
40	Compressed Air	Small	2	1	1	Exhausted
41	Compressed Air	Large	1	1	1	Exhausted
42	HVAC	Very Small	26	4	2	Exhausted
43	HVAC	Small	14	4	1	Exhausted

Strata	Sampling Measure Group	Size	Frame	Target	Sample Completes	Status
44	HVAC	Small to Medium	8	4	1	Exhausted
45	HVAC	Medium to Large	6	4	3	Exhausted
46	HVAC	Large	4	3	3	Exhausted
47	HVAC	Very Large	9	9	0	Exhausted
48	Lighting	Very Small	113	12	28	Available
49	Lighting	Small	42	12	12	Available
50	Lighting	Small to Medium	24	12	7	Exhausted
51	Lighting	Medium to Large	17	11	3	Exhausted
52	Lighting	Large	13	11	5	Exhausted
53	Lighting	Very Large	11	11	3	Exhausted
54	Motors and Drives	Small	6	3	1	Exhausted
55	Motors and Drives	Medium	3	3	1	Exhausted
56	Motors and Drives	Large	1	1	1	Exhausted
57	Process	Small	3	2	3	Exhausted
58	Process	Large	1	1	1	Exhausted
59	Refrigeration	Very Small	23	5	6	Available
60	Refrigeration	Small	11	5	6	Available
61	Refrigeration	Small to Medium	9	5	3	Exhausted
62	Refrigeration	Medium to Large	7	5	2	Exhausted
63	Refrigeration	Large	6	4	5	Exhausted
64	Refrigeration	Very Large	6	6	0	Exhausted
65	Other	Small	3	2	0	Exhausted
66	Other	Large	1	1	1	Exhausted
67	HVAC	All	1	1	0	Exhausted
68	Refrigeration	Very Small	76	7	14	Available
69	Refrigeration	Small	45	7	16	Available
70	Refrigeration	Medium	33	7	11	Available
71	Refrigeration	Large	24	7	13	Available
72	Refrigeration	Very Large	16	6	8	Exhausted
73	Process	Small	1	1	1	Exhausted
74	Process	Large	1	1	0	Exhausted
Total			**881**	**310**	**275**	

F-4 Dispositions By Strata - Custom Gas

Strata	Sampling Measure Group	Size	Frame	Target	Sample Completes	Status
1	Building Envelope	Small	5	2	4	Exhausted
2	Building Envelope	Large	2	2	2	Exhausted
3	HVAC	Small	8	4	2	Exhausted
4	HVAC	Medium	3	3	2	Exhausted
5	HVAC	Large	1	1	0	Exhausted
6	Water Heater	All	3	1	1	Exhausted
7	Process	All	1	1	0	Exhausted
8	Building Envelope	Small	2	1	0	Exhausted
9	Building Envelope	Large	1	1	0	Exhausted
10	HVAC	Small	9	4	2	Exhausted
11	HVAC	Medium	5	4	1	Exhausted
12	HVAC	Large	4	4	1	Exhausted
13	Water Heater	All	2	1	1	Exhausted
14	Process	Small	2	1	1	Exhausted
15	Process	Large	1	1	0	Exhausted
16	Building Envelope	Very Small	11	4	4	Exhausted
17	Building Envelope	Small	6	4	3	Exhausted
18	Building Envelope	Medium	5	4	3	Exhausted
19	Building Envelope	Large	4	3	2	Exhausted
20	Building Envelope	Very Large	5	5	2	Exhausted
21	HVAC	Very Small	35	4	6	Available
22	HVAC	Small	16	4	4	Available
23	HVAC	Large	9	3	1	Exhausted
24	HVAC	Very Large	1	1	0	Exhausted
25	Water Heater	Small	24	5	5	Exhausted
26	Water Heater	Large	11	5	6	Exhausted
27	Building Envelope	Small	5	2	2	Exhausted
28	Building Envelope	Large	2	2	1	Exhausted
29	HVAC	Very Small	24	5	6	Exhausted
30	HVAC	Small	11	4	3	Exhausted
31	HVAC	Medium	5	4	2	Exhausted
32	HVAC	Large	5	4	1	Exhausted
33	HVAC	Very Large	5	5	4	Exhausted
34	Water Heater	Small	4	2	2	Exhausted
35	Water Heater	Large	2	2	2	Exhausted
36	Other	Small	6	3	1	Exhausted
37	Other	Large	2	2	0	Exhausted

Strata	Sampling Measure Group	Size	Frame	Target	Sample Completes	Status
38	Building Envelope	Very Small	10	5	6	Exhausted
39	Building Envelope	Small	8	4	7	Exhausted
40	Building Envelope	Medium	6	4	6	Exhausted
41	Building Envelope	Large	5	4	2	Exhausted
42	Building Envelope	Very Large	5	5	2	Exhausted
43	HVAC	Very Small	16	4	3	Exhausted
44	HVAC	Small	6	3	1	Exhausted
45	HVAC	Large	5	3	1	Exhausted
46	HVAC	Very Large	2	2	1	Exhausted
47	Water Heater	Small	6	3	4	Exhausted
48	Water Heater	Large	3	3	2	Exhausted
49	Process	All	4	2	0	Exhausted
50	Process	All	1	1	0	Exhausted
Total			**324**	**151**	**112**	

Appendix G. SENSITIVITY ANALYSIS – IMPACT OF IMPUSTED MISSING VALUES ON RESULTS

DNV KEMA tested the sensitivity of the NEI to savings ratios to the filling of missing values by calculating the ratio of NEIs to savings with the following changes:

1. Dropped 11 observations where the respondent could not assign any value to the NEIs, but indicated that they were sure of a benefit or cost and
2. Set to zero the portion of the NEIs that were filled: ie. if a measure had NEIs reported for Materials Handling and O&M, but did not know a key input for O&M, we set the O&M NEI to zero and retained the Materials Handling NEI in the comparison ratios.

Tables G-1 through G-4 show the final ratios as reported in Section 4 and the comparison ratios created for the sensitivity analysis. Both the Custom Electric and Prescriptive Gas studies showed statistically significant differences when the fill values were removed, while the Prescriptive Electric and Custom Gas studies did not have any statistically significant differences. While statistically significant, the comparison ratios were all well within the 90% confidence interval of the reported ratio.

The values used to fill were not themselves extreme values (being averages), nor were the resulting NEIs that resulted after the fill larger than most. The difference in ratio values could be attributed to having a value vs. not having a value. Since all measures that received a fill value had responses they both experienced NEIs and that they knew that those NEIs were a benefit, ignoring their NEIs by assigning a zero value systemically underestimates the NEIs. By filling the missing values the resulting ratios avoid this systemic underestimation.

Table G-1. Comparison of results with and without imputed missing values – Prescriptive Electric

NEI Reporting Category	Reported Ratio				Comparison Ratio (Without Fill Values)				Significantly Different?
	n	NEI/kWh	90% CI Low	90% CI High	n	NEI/kWh	90% CI Low	90% CI High	
Compressed Air	27	$ 0.0966	$ 0.0544	$ 0.1389	24	$ 0.0948	$ 0.0513	$ 0.1383	No
HVAC	163	$ 0.0274	$ 0.0176	$ 0.0372	161	$ 0.0266	$ 0.0168	$ 0.0364	No
Lighting	50	$ 0.0043	$ (0.0005)	$ 0.0091	49	$ 0.0035	$ (0.0011)	$ 0.0081	No
Motors and Drives	30	$ 0.0013	$ (0.0002)	$ 0.0028	30	$ 0.0013	$ (0.0002)	$ 0.0028	No
Refrigeration	32	$ 0.0039	$ (0.0002)	$ 0.0079	32	$ 0.0039	$ (0.0002)	$ 0.0079	No
Overall	**302**	**$ 0.0274**	**$ 0.0188**	**$ 0.0360**	296	$ 0.0265	$ 0.0180	$ 0.0351	No

Table G-1. Comparison of results with and without imputed missing values – Prescriptive Electric – Prescriptive Gas

NEI Reporting Category	Reported Ratio				Comparison Ratio (Without Fill Values)				Significantly Different?
	n	NEI/Therm	90% CI Low	90% CI High	n	NEI/Therm	90% CI Low	90% CI High	
Building Envelope	2	$ 3.6151	$ 2.6418	$ 4.5885					N/A
HVAC	50	$ 1.3464	$ 0.5433	$ 2.1496	48	$ 0.9568	$ 0.2828	$ 1.6307	Yes
Water Heater	47	$ 0.2604	$ (0.0012)	$ 0.5221	47	$ 0.2247	$ (0.0153)	$ 0.4648	No
Overall	**99**	**$ 0.8344**	**$ 0.3634**	**$ 1.3053**	95	$ 0.6016	$ 0.2060	$ 0.9972	Yes

Table G-1. Comparison of results with and without imputed missing values – Prescriptive Electric - Custom Electric

NEI Reporting Category	Reported Ratio				Comparison Ratio (Without Fill Values)				Significantly Different?
	n	NEI/kWh	90% CI Low	90% CI High	n	NEI/kWh	90% CI Low	90% CI High	
CHP/Cogen	6	$ (0.0147)	$ (0.0247)	$ (0.0047)	6	$ (0.0147)	$ (0.0247)	$ (0.0047)	No
HVAC	20	$ 0.0240	$ 0.0003	$ 0.0477	20	$ 0.0240	$ 0.0003	$ 0.0477	No
Lighting	89	$ 0.0594	$ 0.0318	$ 0.0871	88	$ 0.0595	$ 0.0315	$ 0.0876	No
Motors and Drives	42	$ 0.0152	$ (0.0005)	$ 0.0309	42	$ 0.0152	$ (0.0005)	$ 0.0309	No
Refrigeration	90	$ 0.0474	$ 0.0244	$ 0.0705	90	$ 0.0474	$ 0.0244	$ 0.0705	No
Other	29	$ 0.0562	$ 0.0038	$ 0.1087	28	$ 0.0381	$ (0.0046)	$ 0.0808	Yes
Overall	**276**	**$ 0.0368**	**$ 0.0231**	**$ 0.0506**	274	$ 0.0333	$ 0.0203	$ 0.0462	Yes

Table G-1. Comparison of results with and without imputed missing values – Prescriptive Electric Custom Gas

NEI Reporting Category	Reported Ratio				Comparison Ratio (Without Fill Values)				Significantly Different?
	n	NEI/Therm	90% CI Low	90% CI High	n	NEI/Therm	90% CI Low	90% CI High	
Building Envelope	46	$ 0.4774	$ 0.1258	$ 0.8290	46	$ 0.4774	$ 0.1258	$ 0.8290	No
HVAC	41	$ 0.2291	$ 0.1522	$ 0.3060	40	$ 0.2284	$ 0.1448	$ 0.3119	No
Water Heater	23	$ 0.1824	$ (0.4953)	$ 0.8601	23	$ 0.1824	$ (0.4953)	$ 0.8601	No
Other	2	$ 0.5253	$ (5.6577)	$ 6.7083	2	$ 0.5253	$ (5.6577)	$ 6.7083	No
Overall	**112**	**$ 0.2473**	**$ 0.1490**	**$ 0.3455**	111	$ 0.2468	$ 0.1435	$ 0.3501	No

Appendix H. RECOMMENDED NON-ENERGY IMPACT RATIOS BY PROGRAM ADMINISTRATOR

This appendix provides the specific NEI ratios that DNV KEMA recommends National Grid and NStar apply to their programs. These recommendations are more specific to the individual PA's program mapping than those presented in Section 4. The reporting categories used in this report are aggregations of the categories used by the individual PAs to categorize measures installed through their programs. Both NGrid and NStar requested DNV KEMA provide recommendations as to what NEI ratios apply to the measure groups that they use in their tracking systems. The following tables (Table H-1 and H-2) provide the "best fit" and most conservative options that the PAs have for estimating NEIs in their models using this study.

Table H-1. NGRID Recommended Reporting Categories

Fuel	BCR Activity	Program	Measure	Applicable NEI: Best Fit Reporting Category	Best Fit Value	Conservative Reporting Category	Conservative Value
Electric	C03a Large C&I Retrofit	C03a C&I Large Retrofit	EI Compressed Air	Zero	0.000	Zero	0.000
Electric	C03a Large C&I Retrofit	C03a C&I Large Retrofit	EI Custom	Custom Overall	0.037	Custom Overall	0.037
Electric	C03a Large C&I Retrofit	C03a C&I Large Retrofit	EI HVAC	Prescriptive HVAC	0.097	Prescriptive HVAC	0.097
Electric	C03a Large C&I Retrofit	C03a C&I Large Retrofit	EI Light	Prescriptive Lighting	0.027	Prescriptive Lighting	0.027
Electric	C03a Large C&I Retrofit	C03a C&I Large Retrofit	EI Motors	Zero	0.000	Zero	0.000
Electric	C03a Large C&I Retrofit	C03a C&I Large Retrofit	EI VSDs	Zero	0.000	Zero	0.000
Electric	C03b Small C&I Retrofit	C03b C&I Small Retrofit	SCI	Zero	0.000	Zero	0.000
Electric	C03a Large C&I Retrofit	C03a C&I Large Retrofit	CHP Systems All	Custom CHP/Cogen	-0.015	Custom CHP/Cogen	-0.015
Gas	C03a C&I Retrofit	C&I Retrofit	Pre Rinse Spray Valve	Zero	0.00	Zero	0.00
Gas	C03a C&I Retrofit	C&I Retrofit	Boiler Reset Controls (retrofit only)	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	C03a C&I Retrofit	C&I Retrofit	Steam Traps	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	C03a C&I Retrofit	C&I Retrofit	Thermostat	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	C03a C&I Retrofit	C&I Retrofit	Custom Retrofit	Custom Overall	0.25	Custom Overall	0.25
Gas	C03a C&I Retrofit	C&I Retrofit	Econ Redevelopment - Retrofit	Zero	0.00	Zero	0.00
Gas	C03a C&I Retrofit	C&I Retrofit	Multifamily Retrofit	Zero	0.00	Zero	0.00
Gas	C03b Small C&I Retrofit	C&I Direct Install	Pre Rinse Spray Valve	Zero	0.00	Zero	0.00
Gas	C03b Small C&I Retrofit	C&I Direct Install	Thermostat	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	C03b Small C&I Retrofit	C&I Direct Install	Boiler Reset	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	C03b Small C&I Retrofit	C&I Direct Install	Faucet Aerator	Zero	0.00	Zero	0.00
Gas	C03b Small C&I Retrofit	C&I Direct Install	Low Flow Shower Head	Zero	0.00	Zero	0.00
Gas	C03b Small C&I Retrofit	C&I Direct Install	Pipe Insulation	Zero	0.00	Zero	0.00
Gas	C03b Small C&I Retrofit	C&I Direct Install	Duct Insulation	Prescriptive HVAC	1.35	Zero	0.00
Gas	C03a C&I Retrofit	Commercial Building Practices and Demonstration Program	Commercial Building Practices and Demonstration Program	Zero	0.00	Zero	0.00
Gas	C06x Hard to Measure	Deep Energy Retrofit - Commercial	Deep Energy Retrofit - Commercial	Custom Overall	0.25	Zero	0.00
Gas	C06x Hard to Measure	Business Energy Analyzer	Business Energy Analyzer	Custom Overall	0.25	Zero	0.00

H-2. NStar Recommended Reporting Categories

Fuel	Program	Measure	Applicable NEI			
			Best Fit		Conservative	
			Reporting Category	Value	Reporting Category	Value
Electric	C&I Retrofit	Compressed Air - Custom	Custom Other	0.056	Zero	0.000
Electric	C&I Retrofit	Compressed Air - Prescriptive	Zero	0.000	Zero	0.000
Electric	C&I Retrofit	HVAC - Custom	Custom HVAC	0.024	Custom HVAC	0.024
Electric	C&I Retrofit	HVAC - Prescriptive	Prescriptive HVAC	0.097	Prescriptive HVAC	0.097
Electric	C&I Retrofit	Process	Custom Other	0.056	Zero	0.000
Electric	C&I Retrofit	Lighting - Custom	Custom Lighting	0.059	Custom Lighting	0.059
Electric	C&I Retrofit	Lighting - Prescriptive	Prescriptive Lighting	0.027	Prescriptive Lighting	0.027
Electric	C&I Retrofit	Motors & VFD - Custom	Zero	0.000	Zero	0.000
Electric	C&I Retrofit	Motors & VFD - Prescriptive	Zero	0.000	Zero	0.000
Electric	C&I Retrofit	Refrigeration - Custom	Custom Refrigeration	0.047	Custom Refrigeration	0.047
Electric	C&I Retrofit	Refrigeration - Prescriptive	Custom Refrigeration	0.047	Custom Refrigeration	0.047
Electric	C&I Retrofit	CHP	Custom CHP/Cogen	-0.015	Custom CHP	-0.015
Electric	C&I Retrofit	Food Services - Custom	Custom Other	0.056	Zero	0.000
Electric	C&I Retrofit	Food Services - Prescriptive	Zero	0.000	Zero	0.000
Electric	C&I Small Retrofit	HVAC	Prescriptive HVAC	0.097	Prescriptive HVAC	0.097
Electric	C&I Small Retrofit	Process	Custom Other	0.056	Zero	0.000
Electric	C&I Small Retrofit	Lighting - Fixture	Prescriptive Lighting	0.027	Prescriptive Lighting	0.027
Electric	C&I Small Retrofit	Lighting - Control	Prescriptive Lighting	0.027	Prescriptive Lighting	0.027
Electric	C&I Small Retrofit	Refrigeration	Custom Refrigeration	0.047	Custom Refrigeration	0.047
Electric	C&I Small Retrofit	Motors & VFD	Zero	0.000	Zero	0.000
Electric	C&I Small Retrofit	Hot Water	Zero	0.000	Zero	0.000
Gas	C&I Retrofit	Programmable Thermostats	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	C&I Retrofit	Boiler Reset Controls	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	C&I Retrofit	Steam Traps	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	C&I Retrofit	Ozonated Laundry Systems	Zero	0.00	Zero	0.00
Gas	C&I Retrofit	Custom Retrofit	Custom Overall	0.25	Zero	0.00
Gas	Direct Install	Pre-Rinse Spray Valves	Zero	0.00	Zero	0.00
Gas	Direct Install	Programmable Thermostats	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	Direct Install	Boiler Reset Controls	Zero	0.00	Zero	0.00
Gas	Direct Install	Faucet Aerators	Zero	0.00	Zero	0.00
Gas	Direct Install	Salon Sprayers	Zero	0.00	Zero	0.00
Gas	Direct Install	Pipe Insulation	Zero	0.00	Zero	0.00
Gas	Direct Install	Showerheads	Zero	0.00	Zero	0.00
Gas	Direct Install	Duct Sealing & Insulation	Prescriptive HVAC	1.35	Prescriptive HVAC	1.35
Gas	Direct Install	Custom DI	Custom Overall	0.25	Zero	0.00

Massachusetts Electric and Gas Program Administrators

Stage 2 Results—Commercial and Industrial New Construction Non-Energy Impacts Study—Final Report

March 24, 2016

Prepared by:

DNV GL

Part of the Special and Cross-Cutting Evaluation Program Area

Tetra Tech
6410 Enterprise Lane, Suite 300 | Madison, WI 53719
Tel 608.316.3700 | Fax 608.661.5181
www.tetratech.com

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1. EXECUTIVE SUMMARY

This report presents the methodology and results of the 2015 Non-Energy Impact (NEI) Study of energy efficiency measures supported through the Massachusetts Program Administrators' (PAs) Commercial and Industrial (C&I) New Construction (NC) Programs. This study was conducted in two separate phases by DNV GL and Tetra Tech (the Evaluation Team) under the Cross-Cutting Research area for the Massachusetts PAs and the Energy Efficiency Advisory Council (EEAC) consultants. Findings from Stage 1, which focused on recommending an approach to estimate NEIs, were summarized in a separate document; this current report provides the findings from Stage 2.

A major consideration when estimating NEIs for NC measures was distinguishing between NEIs resulting from the measure being *new* versus being *energy efficient.* Because the facilities considered in this analysis were either new or substantially renovated, some type of new equipment would be installed regardless of participation in an energy efficiency program. Consequently, NEIs associated with the early retirement of existing equipment are excluded from this study, and only NEIs associated with moving from the baseline "new" technology to a more energy-efficient piece of equipment are relevant. NEIs evaluated in this report include any positive or negative effects other than energy savings that are attributable to the adoption of more energy-efficient equipment. Examples of positive NEIs include reduced labor or non-labor operations and maintenance (O&M) costs, and increased revenue. Negative NEIs include increased labor or O&M costs, or reduced productivity or sales.

1.1 OBJECTIVES

The purpose of this study was to quantify the dollar value of participant NEIs for C&I NC projects completed in 2013, and to estimate gross NEIs per unit of energy savings resulting from NC electric and gas measures separately.

The study was completed in two stages. Stage 1 determined the best approach for estimating NEIs from NC measures. Based on the results of the Stage 1 research, this Stage 2 analysis focuses on the NEIs associated with "true" new construction measures only. True new construction measures are defined as:

- New buildings/facilities
- Major renovations.

However, this does not include early retirement, upstream, or replace on failure (ROF)/natural replacement.[1]

[1] As of 2013, the PAs included four types of projects under the new construction program: new buildings, major retrofits, replacement of measures at the end of their useful life (replace on failure/natural replacement), and measures installed through the upstream program. For reasons documented in the Stage 1 research, the Evaluation Team decided to focus this analysis on new buildings and major retrofits only, defined herein as "true" new construction.

A more detailed list of objectives for each stage of the analysis is provided in Section 2.2 of this report.

1.2 OVERVIEW OF APPROACH

To quantify the NEIs associated with the NC program in 2013, the Evaluation Team first reviewed the methodology used in a related study that examined NEIs associated with the 2012 C&I Retrofit program.[2] The Evaluation Team considered using the same approach as the 2012 study, but ultimately decided a different approach was needed for new construction. A two-stage approach was selected to address uncertainty regarding respondents' ability to conceptualize cost and revenue differences associated with program-rebated measures relative to a hypothetical scenario using non-efficient technologies.

In Stage 1 of this study, DNV GL conducted two major tasks to determine the most effective means of obtaining NEI information for NC measures:

1. We analyzed the 2013 program tracking data and the 2012 C&I NEI Retrofit study results
2. We conducted in-depth interviews with four groups of market actors (PA staff, design firms, manufacturers and suppliers, and customer energy managers and operations groups).[3]

Stage 1 of this study found that, in contrast to the situation for retrofit measures addressed in the 2012 report, interview respondents often have difficulty self-reporting NEIs associated with NC measures. For NC, respondents do not have an observed point of comparison to gauge the difference between operating costs and/or sales for the new energy-efficient equipment versus costs/sales for a hypothetical baseline equipment that is "new, but not energy efficient."

Therefore, Stage 2 of this study did not rely on self-reports to quantify project-level NEIs, but did use data collected through interviews to inform the analysis. NEIs were instead estimated through the following basic steps.

- True NC projects were identified from the PAs' tracking data, and a sample of measures was drawn from those true NC projects.
- An engineering/lifecycle cost analysis was performed for each sampled measure.
- The NEI per energy savings results from these analyses were rolled up to the appropriate benefit-cost (BC) categories used by the PAs.

The engineering approach employed data from published sources, data from interview responses, and information from PA tracking data.

[2] Final Report – Commercial and Industrial Non-Energy Impacts Study. Prepared by DNV GL for the Massachusetts Program Administrators and EEAC Consultants. June 29, 2012.
[3] A more comprehensive discussion of preliminary and Stage 1 research is provided in 5.2APPENDIX B: of this report.

A more comprehensive discussion of our Stage 2 study approach is provided in Section 3 of this report.

1.3 KEY FINDINGS & RECOMMENDATIONS

Based on our analysis, the total annual value of NEIs for 2013 NC program participants that conducted true NC projects was roughly $488,000 per year, across 957 measures installed in 2013. These results include the Custom – Comprehensive Design Analysis (CDA) performance path-based measure.[4] Table 1 provides a breakdown of savings by project track.[5]

Table 1. Estimated Annual NEIs

Project Track	Annual NEI
Custom Electric	$ 89,261
Prescriptive Electric	$ 372,353
Custom Gas	$ (3,643)
Prescriptive Gas	$ 30,151
Total	**$ 488,122**

Table 2 and Table 3 show DNV GL's recommended unit NEI estimates for each of the measure categories used in the PAs' BC analysis. For each of the BC measure categories, we show the unit NEI in dollars per kWh or per therm and its statistical significance. These NEI estimates are derived using the engineering-based analysis that we conducted on a sample of 255 of the population of 957 NC measures installed in 2013. For BC measure categories for which we had sufficient sample data, the recommended value is based on data from that specific category alone. In other cases, it was necessary to combine similar measure categories at the sampling or analysis stage (herein referred to as a "sample category"). For example, DNV GL recommends using the prescriptive commercial kitchen NEI estimate for the Custom Food Service benefit cost category since there were no custom commercial kitchen measures in the sample frame.

We provide NEI estimates for several measure categories even though they are not statistically significant at the 10% significance level or better. We recommend using these estimates for the PAs' BC model. In these cases, the lack of statistical significance is likely due to small sample sizes, and the estimates provided are the best available from the study. Where the NEI estimate is listed as "N/A" in the tables, the respective measure category did

[4] The total annual value is calculated by summing the products of DNV GL's derived $NEI/unit of energy savings factor and the PAs' reported 2013 annual energy savings for each measure. CDA projects constitute a single measure category in the PAs' BC analysis, although they likely involve the installation of multiple technologies or measures to meet the requisite performance path-based standard for the whole building or building system.

[5] The estimates shown in Table 1 are intended to illustrate the estimated magnitude of the total annual NEIs realized for true NC projects in 2013 because they include NEIs for some measure categories that did not meet the test for statistical significance.

not appear in our sample. Where the NEI estimate is listed as a zero, the analysis indicates that the NEI for that measure category is negligible.

DNV GL recommends that the PAs apply the electric and gas NEIs presented in Table 2 and Table 3, respectively. However, we note the following limitations to our analysis:

- The approach used to isolate true NC projects (and their measures) limits this study to those measures contained in the Dodge data or tax assessors' data that were the basis for the study samples.
- This study focuses on operational cost impacts only, as these are the changes that can be quantified under our engineering-based approach. Further research is required to explore whether there are additional sources of NEIs.

A more comprehensive discussion of Stage 2 study findings and recommendations is provided in Section 5 of this report.

Table 2. Recommended Electric NEI Estimates by PA Benefit-Cost Measure Category

	Benefit- Cost Category	Sample Category	Overall NEI/kWh	Statistically Significant?	Source of Recommended NEI
Custom					
	CHP	N/A	**N/A**	Not Studied	Not Sampled
	Comprehensive Design	Comprehensive Design	**$ 0.001**	Not Recommended	Custom Electric Comprehensive Design
	Compressed Air	Compressed Air	**$ 0.026**	b	Custom Compressed Air
	Food Services	Commercial Kitchen	**$ 0**	0	Prescriptive Electric Commercial Kitchen
	HVAC	HVAC	**$ 0.001**	a	Custom Electric HVAC/Heat Recovery
	Lighting	Lighting	**$ 0.003**	a	Custom Electric Lighting
	Motors & VFD	Motors	**$ 0**	0	Custom Electric Motors
	Other	Other	**$ 0**	0	Custom Electric Other
	Process	Industrial Process	**$ 0.013**	b	Custom Electric Industrial Process
	Refrigeration	Refrigeration	**$ 0.012**	b	Custom Electric Refrigeration
	Overall	**Overall**	**$ 0.006**	**c**	**Custom Electric Overall**
Prescriptive					
	Compressed Air	Compressed Air	**$ 0.038**	c	Prescriptive Compressed Air
	Food Services	Commercial Kitchen	**$ 0**	0	Prescriptive Electric Commercial Kitchen
	HVAC	HVAC	**$ 0**	0	Prescriptive Electric HVAC
	Lighting	Lighting	**$ 0.020**	c	Prescriptive Electric Lighting
	Motors & VFD	Motors	**$ 0**	0	Prescriptive Electric Motors
	Overall	**Overall**	**$ 0.016**	**c**	**Prescriptive Electric Overall**

a: Recommended, but not well determined ($.10 < p \leq .50$)

b: Recommended, statistically significant at 90% confidence ($p \leq .10$)

c: Recommended, statistically significant at 99% confidence ($p \leq .01$)

0: NEIs are determined to be negligible

Not Recommended: $p > .5$

Not Studied: No measures of this type in our sample

Table 3. Recommended Gas NEI Estimates by PA Benefit-Cost Measure Category

	Benefit- Cost Category	Sample Category	Overall NEI/Therm	Statistically Significant?	Source of Recommended NEI
Custom					
	Building Shell	Building Shell	$ 0	0	Custom Gas Building Shell
	Comprehensive Design	Comprehensive Design	$ (0.004)	a	Custom Gas Comprehensive Design
	Condensing Boiler	Boilers	$ (0.006)	a	Custom Gas Boilers
	Combination Boiler/Hot Water Heater	Boilers	$ (0.006)	a	Custom Gas Boilers
	Condensing Unit Heater	Other Gas Heating	$ 0	0	Custom Gas Other Gas Heating
	Food Services	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Furnace	Other Gas Heating	$ 0	0	Custom Gas Other Gas Heating
	Heat Recovery	HVAC/ Heat Recovery	$ 0.000	a	Custom HVAC/ Heat Recovery
	Heating	Other Gas Heating	$ 0	0	Custom Gas Other Gas Heating
	Hot Water	HVAC/ Heat Recovery	$ 0.000	a	Custom HVAC/ Heat Recovery
	HVAC/ Heat Recovery	HVAC/ Heat Recovery	$ 0.000	a	Custom HVAC/ Heat Recovery
	Infrared Heaters	Other Gas Heating	$ 0	0	Custom Gas Other Gas Heating
	Other	Other	$ (0.032)	a	Custom Gas Other
	Process	Industrial Process	$ 0.007	Not Recommended	Custom Gas Industrial Process
	Overall	**Overall**	**$ (0.005)**	**b**	**Custom Gas Overall**
Prescriptive					
	Combination Oven	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Condensing Boiler	Boilers	$ (0.084)	c	Prescriptive Gas Boilers
	Combination Boiler/Hot Water Heater	Boilers	$ (0.084)	c	Prescriptive Gas Boilers
	Condensing Unit Heater	Other Gas Heating	$ 0.053	c	Prescriptive Gas Other Gas Heating
	Convection Oven	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Conveyer Oven	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Food Services	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Fryer	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Furnace	Other Gas Heating	$ 0.053	c	Prescriptive Gas Other Gas Heating
	Griddle	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Heating	Other Gas Heating	$ 0.053	c	Prescriptive Gas Other Gas Heating
	Hot Water	HVAC/ Heat Recovery	$ 0.242	a	Prescriptive Gas HVAC/ Heat Recovery
	HVAC/ Heat Recovery	HVAC/ Heat Recovery	$ 0.242	a	Prescriptive Gas HVAC/ Heat Recovery
	Infrared Heaters	Other Gas Heating	$ 0.053	c	Prescriptive Gas Other Gas Heating
	Rack Oven	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Steamer	Commercial Kitchen	$ 3.399	b	Prescriptive Gas Commercial Kitchen
	Overall	**Overall**	**$ 0.235**	**a**	**Prescriptive Gas Overall**

a: Recommended, but not well determined ($.10 < p \leq .50$)

b: Recommended, statistically significant at 90% confidence ($p \leq .10$)

c: Recommended, statistically significant at 99% confidence ($p \leq .01$)

0: NEIs are determined to be negligible

Not Recommended: $p > .5$

2. INTRODUCTION

DNV GL and Tetra Tech (the Evaluation Team) were engaged by the Massachusetts Program Administrators (PAs) and the Energy Efficiency Advisory Council (EEAC) to quantify participant non-energy impacts (NEIs) associated with the 2013 Commercial and Industrial (C&I) New Construction program. This study was conducted in two separate phases. Findings from Stage 1, which focused on recommending an approach to estimate NEIs, were summarized in a separate document in March 2015. This current report provides the findings from Stage 2.

2.1 BACKGROUND

The New Construction (NC) program is administered by the Massachusetts PAs for both electric and gas measures. It provides incentives and technical services to C&I customers that are building new facilities, undergoing major renovations of an existing facility, or replacing failed equipment (replace on failure or natural replacement measures). It also provides incentives for upstream lighting and HVAC measures.

For NC measures, the issue of NEIs resulting from a measure being new versus being energy efficient is of particular interest, since some type of new equipment would have been installed regardless of participation in an energy efficiency program. Therefore, only NEIs associated with moving from a standard piece of new equipment to an energy efficient piece of new equipment are relevant. NEIs associated with the early retirement of existing equipment are not relevant to this study, and as discussed in Section 2.3, NEIs for replace on failure/natural replacement and upstream measures are not analyzed in this study.

2.2 EVALUATION OBJECTIVES

The Evaluation Team identified the following objectives for this study:

Stage 1 objectives:

1. Review NC measures installed during 2013 to define these measures in terms of (1) types of new construction, and (2) measure category/end use.
2. Assess the effectiveness and most appropriate means of establishing baseline conditions for NEI computations and eliciting self-reported responses through in-depth interviews (IDIs) with various market actors.
3. Determine whether NEIs from NC measures are best estimated from self-reports from participants and/or other market actors, engineering review, Delphi panel, or other techniques.
4. Recommend an approach for the Stage 2 analysis.

Stage 2 objectives:

1. Employ the techniques identified through Stage 1 to establish baseline conditions for participant NEIs associated with true NC measures (i.e., excluding replace on failure/natural replacement and upstream measures).

2. Use an engineering-based approach to quantify the dollar value of participant NEIs for true C&I NC projects completed in 2013. NEIs include any positive or negative effects other than energy savings that are attributable to energy efficiency programs experienced by program participants. Examples of positive NEIs include reduced labor or non-labor operations and maintenance (O&M) costs. Negative NEIs include increased labor or O&M costs.

3. Estimate gross NEIs per unit of energy savings resulting from NC electric and gas measures separately.

2.3 STUDY APPROACH

In Stage 1 of this study, the Evaluation Team conducted a literature review, data mining, and in-depth interviews to meet the Stage 1 research objectives. The Stage 1 evaluation approach is described in more detail in Appendix B.

This Stage 1 research uncovered the following key findings, which provided direction for the Stage 2 research.

- **The analysis of NEIs associated with NC measures should focus on true new construction only.** While the PAs currently include replace on failure/natural replacement and 100% of upstream measures in the New Construction programs—in addition to what we define as “true” new construction measures (i.e., major renovation and new buildings)—the Evaluation Team concluded that the Stage 2 research should focus on true NC only.

- **Self-reports by end users would not provide an effective means for estimating NEIs associated with most NC measures.** Self-reported NEIs from customers or other market actors were not likely to provide meaningful results, since interview respondents had difficulty conceptualizing differences in operations relative to a hypothetical baseline that is new, but not energy efficient. Facility managers reported that if NEIs were assessed on NC projects, they were typically determined by design engineers during the project or facility design phase. This was particularly true of heating and cooling measures.

- **Self-reports by engineering firms would likely provide valuable insights to estimating NEIs across the range of projects for which they perform engineering services.** Given engineering firms’ breadth of knowledge across multiple projects, we concluded it would be valuable to conduct in-depth interviews with this group to gather information regarding key parameters to consider, and scenarios for which those factors may vary when estimating NEIs.

- **An engineering-based approach is warranted to estimate NEIs**. The data mining results suggested that we could utilize the standardized formulas developed through the 2012 C&I NEI Retrofit study as a basis for many NEI computations. DNV GL’s engineers could use measure descriptions, technical reference manuals, and data provided by existing C&I market characterization studies to construct sets of scenarios for examining operational cost and revenue impacts that result from using energy-efficient equipment, compared to standard efficiency measures. Engineers could then use their expertise in conjunction with the available data to construct estimates of these cost and revenue impacts for each measure category.

Based on these Stage 1 research findings—summarized in greater detail in a March 2015 report to the PAs and EEAC[6]—the Evaluation Team recommended (and subsequently employed) an engineering-based approach in Stage 2 to estimate NEIs associated with measures installed through the PAs' New Construction programs.

Stage 2 of this project consisted of the following tasks:

1. **Selection of a sample of true NC measures.** We combined the PAs' tracking data with the Dodge Players database[7] and tax assessors' data to isolate true NC projects, and then selected a sample of measures by BC measure category for our analysis.[8]
2. **Definition of baseline technology for each sampled measure.** We reviewed the Massachusetts Technical Reference Manual (TRM) and other sources to define the appropriate baseline for each sampled measure.
3. **Engineering/life-cycle cost analysis.** We estimated the difference in the average annual life-cycle cost between the baseline and energy-efficient technologies to reflect the NEI for each sampled measure.
4. **Estimation of NEI per unit energy savings.** We computed the average NEI per unit of energy savings to identify statistically significant NEIs for each of the measure categories used in the PAs' benefit cost analysis.

[6] Stage 1 Results and Stage 2 Detailed Research Plan—Commercial and Industrial New Construction Non-Energy Impacts Study—Commercial and Industrial New Construction Non-Energy Impacts Study. Prepared for the Massachusetts Program Administrators and EEAC Consultants. Prepared by DNV GL and Tetra Tech. March 20, 2015.

[7] This database contains information on all known new construction and major renovation projects in the Commonwealth.

[8] For NC measures contained in the PAs' tracking data, DNV GL will provide the PAs with a separate Excel file that maps the estimated NEIs to their appropriate true NC measure. For more recent program years, the PAs have implemented internal processes to isolate true new construction to which the NEI estimates can be more readily applied.

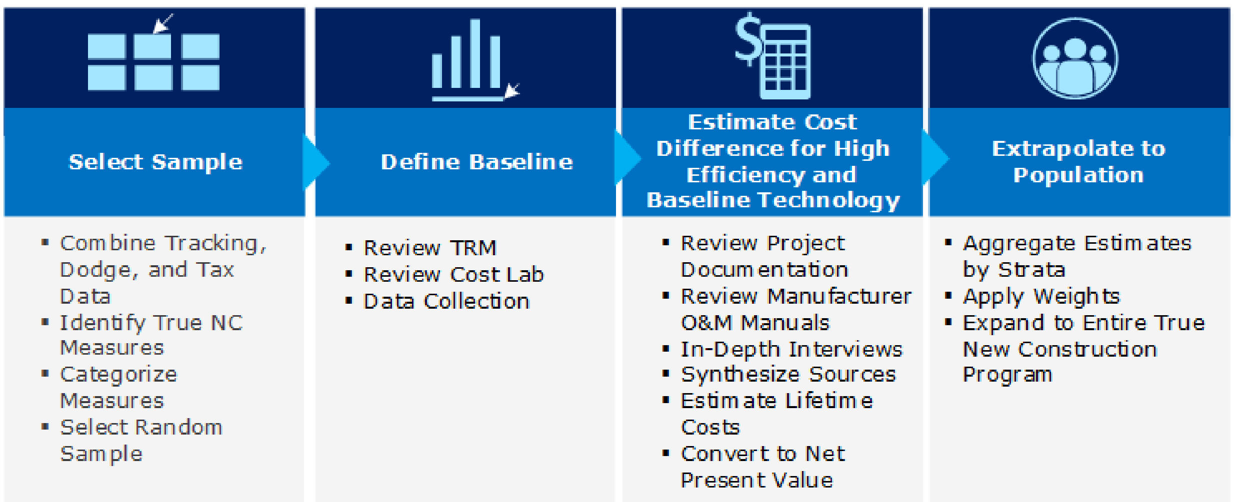
3. METHODOLOGY

3.1 OVERVIEW OF APPROACH

For this evaluation, we used an engineering cost-estimating approach to determine NEIs for true NC projects. We limited the analysis to impacts on operations and maintenance costs. Previous research shows that other sources of NEIs, such as changes in productivity, revenue, and comfort, may also result from energy efficiency measures; however, this study was limited to NEIs resulting from life-cycle cost differences due to the use of an engineering based approach. While in-depth interviews were not used to obtain NEI estimates, we did conduct a limited number of interviews with building owners, engineering firms, and public officials to inform the analysis and provide specific values of parameters needed in the engineering analysis.

Figure 1 provides a high-level overview of our approach, which consisted of four general steps.

Figure 1. Overview of NEI Estimation Process



1. First, we combined the PAs' tracking data with the Dodge Players database and tax assessors' data to isolate true NC projects, and then selected a sample of measures by BC measure category for our analysis.

2. Next, we reviewed the TRM, data contained in and required by Cost Lab, and other sources to construct data collection instruments and define the appropriate baseline for each sampled measure. CostLab is cost estimation software described in detail in Appendix A.

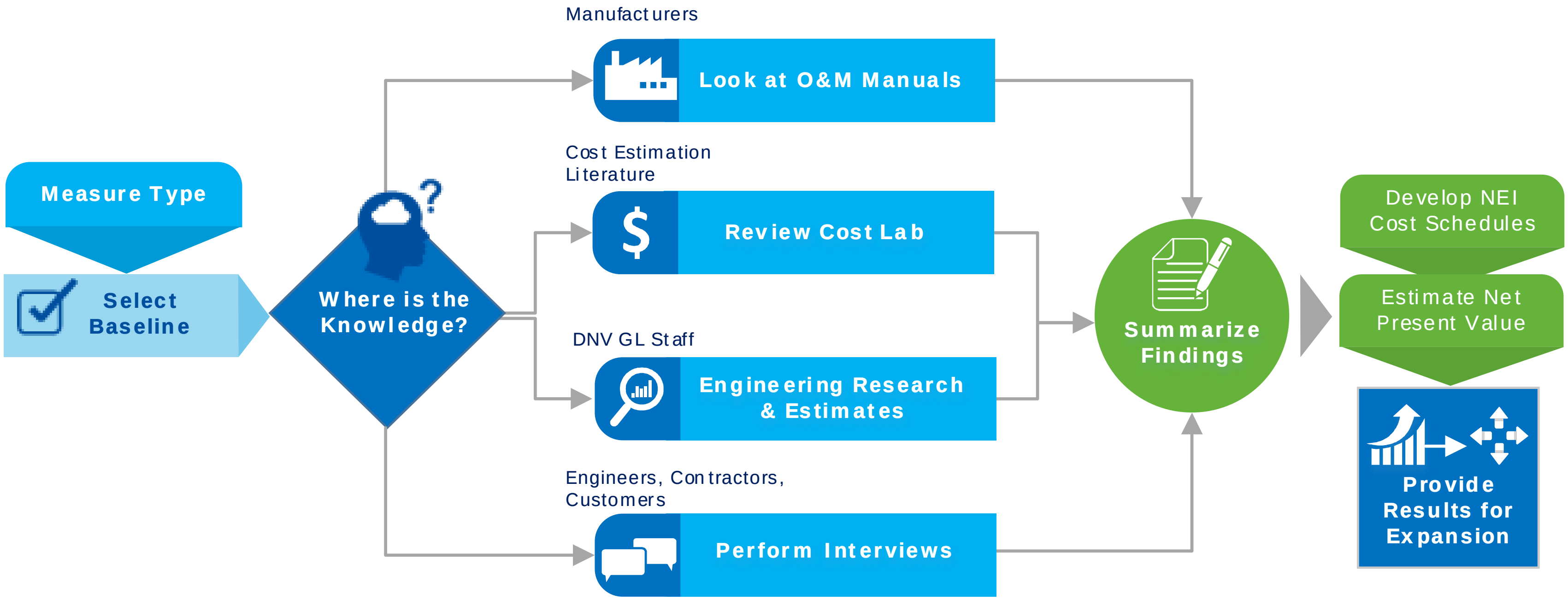
3. In the third step, we estimated the difference in the average annual life-cycle cost between the baseline and energy-efficient technologies to reflect the NEI for each sampled measure.

4. Finally, we computed the average NEI per unit of energy savings to identify statistically significant NEIs for each of the measure categories used in the PAs' BC analysis.

3.2 DATA ACQUISITION

The engineering analysis required data from a variety of sources to develop and corroborate the assumptions used to construct NEI estimates, as shown in Figure 2, which also depicts the flow of information used in our analysis. Each of these sources is discussed in the paragraphs that follow.

Figure 2. Sources of Information used in the Engineering Analysis



Manufacturers' operations and maintenance manuals. Manufacturer-produced operations and maintenance (O&M) manuals were used to provide manufacturer-recommended maintenance and repair schedules, a valuable input to life-cycle cost estimation.

CostLab software. CostLab is cost-estimation software produced by CBRE Whitestone that provides estimates for building O&M costs that many institutions and large businesses use to set their O&M budgets. While CostLab does not offer sufficient detail to differentiate between less and more efficient equipment, it does provide a good reference point for the O&M costs associated with the average piece of equipment or building system. We used these estimates in many cases to establish the baseline costs of ownership to which we would compare our efficient equipment estimates. CostLab provides costs in terms of annual maintenance, periodic repair, and replacement costs.

DNV GL staff. DNV GL's expertise in life-cycle costing provided a valuable resource for developing life-cycle cost estimates, as we were able to leverage engineers experienced in high-performance building design support. Our engineers have significant hands-on experience with Massachusetts-based facilities, enabling them to produce well-informed estimates for the lifetime costs of ownership of most pieces of equipment; we used the other sources of data as checks on our in-house estimates.

In-depth interviews. We performed 30 in-depth interviews with building owners, engineering firms, and public officials, as discussed in the section below.

In general, we attempted to find multiple sources of information to corroborate our findings. Where sources disagreed with one-another, we generally ranked them in the following ways:

- Operations and Maintenance Manuals
- Technical Reference Manual
- CostLab (for baseline costs)
- Interviewees
- DNV GL staff.

This ranking, however, had many exceptions in cases where a particular individual from either DNV GL or an interviewee was clearly the most knowledgeable source as determined by our team of engineers. In some cases, where one source made a positive estimate and the other negative, we chose not to make an estimate at all.

3.2.1 In-depth interview data collection details

In this section, we describe and review the in-depth interviews that provided a primary source of information for the engineering analysis. While the Stage 1 analysis found that end-use self-reports alone would not provide meaningful NEI estimates, the interviews with end users and other market actors provided other valuable information used in the engineering analysis. The in-depth interviews mostly provided procedural information to guide the methodology behind the engineering estimates, and sometimes provided specific data to be used directly in the engineering estimates. We asked each group of market actors to provide the following general insights:

- What benefits or costs do respondents see from energy-efficient equipment on new construction projects?
- How do these differ depending upon whether the project is a new building or a major renovation?
- What are the important technical, structural, and other parameters for determining whether these benefits are present?
- What sources of information can be used to provide estimates for these parameters?
- What are the values for specific technical parameters identified by the engineering staff through our initial review of the sampled measures and life-cycle cost computations?

The in-depth interviews provided the following general insights.

Public officials from government agencies. The Massachusetts Division of Capital Asset Management and Maintenance (DCAMM) provided a number of Facility Operations and Management Plans (FOMP) used to conduct benchmark costing of new facilities in the Commonwealth. While the reports do not compare energy efficient to less efficient options, they do provide a valuable source for assessing the impact of building features on general cost projections.

Engineering firms and contractors. Contractors and engineering firms who bid/perform maintenance contracts provided valuable insights into many of the technical and cost parameters necessary for computing NEIs. These contractors and engineers were better able to provide useful information than other respondent groups because they could compare their experiences across projects. We contacted a number of engineering firms who discussed sources of NEIs outside of O&M, but their responses indicated that, while “these probably exist, I can’t imagine how you’d quantify that.” These responses confirmed our decision to focus primarily on operations and maintenance NEIs in this study.

Building owners (program participants). Owners of industrial, food service, and grocery facilities provided useful information about the lifetimes, maintenance regimens, and certain other NEIs associated with their equipment. The true new construction projects that we reviewed included very few industrial projects. The industrial projects included in our sample were primarily injection-molding machines and uninterruptable power supplies. Our industrial respondents were unwilling to offer quantifiable data to support production increases or decreases for either of these measures. We suspect that injection-molding machines may offer small decreases in downtime, but we were unable to verify this with respondents.

Table 4 presents further details of the in-depth interview findings. These interview results are split into the following categories:

- Maintenance – How does routine maintenance recommended by manufacturers differ between energy efficient and baseline equipment?

- Repair – How does the requirement for repairs differ over the lifetime of energy efficient equipment and baseline equipment?
- Replacement – How do the lifetimes of efficient and baseline equipment differ?
- Other – NEIs that do not fit into one of the other categories. Often associated with unquantified production increases.

Table 4. Summary of Stage 2 In-Depth Interview Findings

Technology	Respondent Type	NEI Category	Interview Findings
Boilers	Contractor	Maintenance	On energy efficiency boilers, exhaust fans and heat exchangers require more frequent maintenance.
		Replacement	Lifespans of condensing vs. non-condensing equipment is a debated topic. Over the years, the quality of condensing equipment has improved in some ways, but decreased in other ways. No contractors were willing to offer specific guidance on the impacts in lifespan associated with a condensing heat exchanger, though many thought there would be a reduction.
Comprehensive Design	Contractor	Other NEI	There aren't any NEIs associated with an increased level of insulation or air sealing in the building shell. Materials selection has more to do with extending or shortening the life, though this is unrelated to MassSave.
	Engineer	Maintenance	There are a lot of items related to controls that can increase maintenance costs. Each additional sensor point requires additional maintenance. This is extremely site-specific in terms of how often they maintain their sensor points and what kind (brand, type, model) of sensors they use.
		Other NEI	There are several code-compliance paths for energy. For comprehensive design projects, a building simulation model is used and compared to a baseline model. In some cases, this allows a building owner to install a less-efficient building system (e.g., a high percentage of glazing) by increasing the efficiency of another component (e.g., lighting). We were unable to identify any specific examples of NEIs being affected by this type of tradeoff.
	Owner	Maintenance	A lot of the energy efficient technologies associated with laboratories require cleaning and calibration. Control settings are often over-ridden. Not able to quantify any experiment-specific benefits of improved controls.
			Similarly to engineers, owners found that controls can be difficult to set up, configure, commission, and keep operating well.
Compressed Air	Engineer	Maintenance	Screw compressors are designed to last the life of the system, compared to reciprocating compressors which require periodic rebuilds.
Food Service	Owner	Maintenance	Some new equipment may require additional water filtration or de-scaling, but this varies more by manufacturer than by efficiency level.
		Other NEI	Efficient equipment performs more effectively, and can cook a higher volume of food using the same amount of space, faster and at a higher quality which results in less waste.
		Repair	There may be differences with regard to reduced repair and cleanup requirements for energy efficient equipment, but responses were inconsistent and not quantifiable.

Summary of Stage 2 In-Depth Interview Findings (Continued)

Technology	Respondent Type	NEI Category	Interview Findings
Hot Water	Contractor	Maintenance	Annual maintenance for energy efficient equipment is typically increased due to descaling requirements.
		Repair	High efficiency equipment—especially indirect or tankless equipment—generally lasts longer and requires fewer repairs such as anode replacements.
		Replacement	Tankless equipment life varies by manufacturer.
Industrial Process	Owner	Maintenance	Uninterruptible Power Supply systems do not offer NEIs. Typically they do not fail but are replaced when they become obsolete because of new technologies. Maintenance is not different between different systems.
			Injection Molding Machines can be oil-filled, hybrid, or full electric. Oil changes result in the primary difference between the different options, with full electric systems not requiring them at all.
		Other NEI	There may be some site-specific NEIs associated with VFDs controlling conveyor belt speed.
Lighting	Contractor	Replacement	Recycling bulbs can add a couple hundred dollars per job. Energy efficient bulbs last longer, reducing recycling costs for the customer over time.
			It is often faster and cheaper to replace an entire fixture versus replacing a ballast.
			Ballasts are replaced every 3-5 years.
	Owner	Maintenance	LEDs require very little maintenance, but no building owners we contacted have replaced their larger LED fixtures yet.
		Repair	Fixtures are often fully replaced rather than simply replacing the ballasts.
		Replacement	Ballasts typically replaced every five years for fluorescents.
			Owners indicate that small LED fixtures seem to have a high failure rate, similar to halogen bulbs.
Motors	Engineer	Other NEI	For energy efficient motors: -There is a reduction of inrush current due to soft start. -Reduced heat due to running at partial load. -The ability to adjust speed which increases productivity. -There is reduced upfront work due to packaged systems coming pre-programmed.
		Replacement	For energy efficient motors: -Bearings can wear faster causing premature failure. -Additional electric components susceptible to failure. -Electrical flux concentrates at specific points inside motor, causing premature failure.
	Owner	Other NEI	Using VFDs offer no NEIs.
Other Gas Heating	Owner	Maintenance	Infrared heaters require less maintenance than other heating methods due to fewer moving parts and a simpler design.
Refrigeration	Contractor	Maintenance	LED lights in refrigerated cases have less maintenance than fluorescent.
		Replacement	There is a suspicion that items in cases which reduce the amount of heat that needs to be removed increases the compressor lifetime, but they cannot quantify this.
		Other NEI	Energy efficient refrigeration equipment might reduce food spoilage, but unable to quantify this effect.

3.3 ENGINEERING ANALYSIS SAMPLE DESIGN

The first step in the engineering analysis was to identify true NC measures that were part of NC projects for which NEI estimates would be produced. The 2013 C&I program tracking database contains data for the PAs' NC programs; while the upstream projects included as part of this program are explicitly identified in the data, there is not a similar identifier for constructing a frame of true NC projects as distinct from replace on failure/natural replacement measures. Therefore, the first step in constructing the sample design was to isolate the true NC measures and stratify or group those measures into the most appropriate segments for sampling.

We matched records from the 2013 C&I program tracking database to records in the Dodge data to eliminate replace on failure/natural replacement measures. We supplemented that analysis with a review of the year the tracked building was constructed (contained in the tax assessors' data) to identify additional new buildings. We identified approximately 20 percent of project locations in the PA NC tracking data as true NC (244 out of 1,206 locations), and determined that approximately 6 percent of all 2011–2013 NC projects listed in the Dodge data (244 out of 4,095 locations) participated in one of the PAs' NC energy efficiency programs. We identified 957 true new construction measures at these 244 locations.

Next, we stratified the true new construction measures by measure type, dividing the population of true new construction projects into four tracks: Prescriptive Electric, Prescriptive Gas, Custom Electric, and Custom Gas. Within each of these tracks, we grouped the individual true NC measures into sample strata (sample categories) according to the specific measure categories/types and end uses that the PAs require for their BC models. This formed the sample frame for the sample of measures used in this study.

We selected the sample in a way that produces an optimally allocated sample for NEI ratio or factor estimation—in this case, NEI$/unit of energy saved. An optimal sample provides the best possible precision for a particular sample size. The sample design was projected to provide relative precision of overall electric or gas NEIs of about 8% to 14% at the 90% confidence level. However, projections for individual measures varied, and in this study, the focus is on individual measure categories, not an overall value for each fuel type.

Table 5 presents the sample frame and sample allocation for prescriptive and custom electric and gas measures. Our sample consisted of 50 custom electric measures drawn from 9 measure types, 114 prescriptive electric measures drawn from 7 measure types, 30 custom gas measures drawn from 7 measure types, and 61 prescriptive gas projects drawn from 4 measure types. This resulted in an overall sample of 255 true NC measures out of a population of 957 measures in the 2013 program tracking data.

Table 5. Sample Design for Engineering Analysis and Expected Relative Precisions

Fuel Type	Project Track	Sample Category	Population Measures	Population Savings (kWh/Therms)	Sampled Measures	Optimistic Relative Precisions	Conservative Relative Precisions
Electric	Custom	Comprehensive Design	13	2,845,172	8	26%	36%
		Compressed Air	5	802,770	4	13%	18%
		HVAC	17	2,348,957	6	33%	47%
		Industrial Process	5	1,565,025	5	0%	0%
		Lighting	24	2,998,970	15	12%	17%
		Motors	4	612,932	4	0%	0%
		Other	2	567,487	2	0%	0%
		Refrigeration	13	2,040,845	5	40%	58%
		Building Shell	1	80,240	1	0%	0%
		Subtotal	**84**	**13,862,398**	**50**	**10%**	**14%**
	Prescriptive	Commercial Kitchen	1	1,364	1	0%	0%
		Compressed Air	23	533,826	10	21%	30%
		HVAC	134	1,104,397	15	29%	41%
		Industrial Process	1	5,389	1	0%	0%
		Lighting	440	2,977,041	49	12%	17%
		Motors	113	2,537,183	37	12%	18%
		Other	1	73,616	1	0%	0%
		Subtotal	**713**	**7,232,816**	**114**	**8%**	**11%**
Gas	Custom	Comprehensive Design	10	267,011	8	11%	16%
		HVAC/ Heat Recovery	12	155,143	7	21%	29%
		Industrial Process	2	20,608	2	0%	0%
		Other	7	46,534	5	11%	16%
		Boilers	10	90,000	5	32%	46%
		Building Shell	1	57	1	0%	0%
		Other Gas Heating	2	46,466	2	0%	0%
		Subtotal	**44**	**625,819**	**30**	**8%**	**12%**
	Prescriptive	Commercial Kitchen	14	8,897	9	20%	29%
		HVAC/ Heat Recovery	27	4,520	13	23%	33%
		Boilers	68	79,296	34	12%	17%
		Other Gas Heating	7	2,138	5	24%	35%
		Subtotal	**116**	**94,851**	**61**	**10%**	**14%**
		Total	**957**	**21,815,884**	**255**		

3.4 SELECTING BASELINES

After stratifying and selecting the sample of measures, the first step in estimating NEIs for each measure was to define the baseline technology from which we could measure facility cost changes relative to the installed energy efficient technology. When estimating NEIs for specific measures, the choice of baseline is crucial. Specific features of the baseline equipment will dictate its maintenance and repair schedules, which is why it is important to choose the correct baseline. For prescriptive measures included in the TRM, we used the associated baselines defined in the TRM; these baselines are typically based upon the

International Energy Conservation Code (IECC) prescriptive code-compliance path. For example, in the IECC, the baseline for an energy-efficient centrifugal air-cooled chiller is a less-efficient centrifugal air-cooled chiller rather than a different kind of chiller.

However, we could utilize TRM baselines only to the extent that they gave us the information we needed. This was limited, because the TRM does not always identify the baseline and efficient equipment features that correlate most strongly with NEIs. As an example, the TRM does not specify a baseline compressor type (such as scroll, screw, or reciprocating) for the High-Efficiency Air Compressor measure. In cases where the TRM did not specify the applicable equipment characteristics, or where the TRM did not address the choice of baseline (such as for custom measures), we selected the most commonly installed code-compliant equipment type as the baseline using our own expertise and experience and the results of our in-depth interviews.

Performance path-based projects, classified as a single BC measure category "Custom – Comprehensive Design Analysis (CDA)," posed a particular challenge for identifying baseline technologies. These performance path-based projects involve the installation of multiple measures across multiple measure categories (e.g., lighting and HVAC) but receive incentives based on the extent to which the new or renovated building or building system as a whole exceeds the efficiency required by code. As noted, for prescriptive and custom measures that are not performance path-based, the baseline is defined in comparison to a specific piece of equipment, using the TRM as a guide where applicable. For performance path-based projects, however, the baseline is not defined based on the equipment but for the building or building system as a whole. The baseline is typically defined by the building simulation modeling assumptions identified in ASHRAE 90.1-2007 Appendix G. In this situation, the baseline for a centrifugal chiller installed in a CDA project could be a screw chiller or even several unitary rooftop units.

To assist in the development of baseline conditions for the performance path-based measure, DNV GL requested that the PAs provide full documentation of the projects. In some cases, the program documentation clearly communicated how the baseline was defined. Where this was missing, the Evaluation Team members used their industry experience and, where appropriate, customer interviews, to determine which baseline code-compliant building system would mostly likely have been installed in the absence of program support.

3.5 ESTIMATING THE COST DIFFERENCES: BASELINE AND ENERGY EFFICIENT TECHNOLOGIES

To estimate the cost differential between the baseline and energy efficient technologies, we constructed detailed cost schedules for the baseline and energy-efficient technologies, which formed the basis for the NEI estimates. Our engineers used repair, replacement, and maintenance costs for baseline and energy-efficient technologies provided by CostLab, our technical knowledge, and reported maintenance and replacement schedules outlined in the manufacturer O&M manuals. Our engineers also used the information obtained from the in-depth interviews to develop or corroborate these costs.

Next, the costs were classified into three types for further analysis:

- *Annual maintenance* – Routine maintenance recommended by manufacturers, such as annual oil changes for reciprocating air compressors. The frequency and costs for maintenance activities can differ between baseline and installed equipment.
- *Periodic repair* – Many types of equipment require repairs during their lifetimes, while other types are not repaired but simply disposed of. For example, a reciprocating air compressor is likely to require a simple rebuild every three years whereas a screw compressor does not. Other types of equipment are simply disposed of rather than repaired, such as many types of light fixtures.
- *Replacement* – For equipment for which the baseline option is likely to fail before the end of the useful life of the energy-efficient equipment, we included and amortized the cost of replacement of the option with a shorter lifetime. We considered the type of equipment that would be installed as a replacement to represent the baseline condition, and found that owners replace equipment in-kind with similar equipment in most cases, except for lighting. Given the rapid adoption of more energy efficient LED lighting, we assumed that baseline lighting equipment would be replaced in-kind with a similar type of lighting for the first replacement cycle, but with LED lighting for subsequent replacement cycles. This is discussed in more detail below.

Once we developed the NEI cost schedules and cost breakdowns, the life-cycle costs were amortized to provide the average annual cost of maintaining the baseline and energy-efficient equipment using the following formula:

$$A = P\frac{r(1+r)^n}{(1+r)^n - 1}$$

Where:

A = payment Amount per year

P = initial Principal (loan amount)

r = interest rate per year

n = total number of payments or periods

Once all costs were included, we calculated the net present value using the following formula:

$$NPV = \sum\left(\frac{A}{(1+r)^n}\right)$$

Where:

A = cost Amount per year

r = interest rate per year

n = applicable number of payments

We assumed the following in computing the NPV of life-cycle costs:

- *Planning horizon* – For each line item, we defined the measure life of the longer-lasting piece of equipment (installed or baseline) to contrast the life-cycle costs.
- *Discount rate* – We applied a discount rate of 0.44%, as reported in the 2016–2018 Three-Year Plan.[9]
- *Capital replacement* – Equipment replaced prior to the end of the planning horizon was assumed to be replaced in-kind and amortized over its useful life. The annual payment of that equipment appeared as a liability starting in the year the equipment was replaced until the end of the planning horizon. For example, if the baseline technology will be replaced in year 10 of a 15-year planning horizon, we amortized the value of the new equipment starting in year 10 over a 10-year planning horizon, so there would be a replacement cost appearing as a liability in years 10 through 15. The difference in the average annual cost of the energy-efficient and baseline technologies is the estimated NEI for each measure.

3.5.1 NEI computations by measure category

This section provides detailed examples of NEI computations for two measure categories. The first example is for lighting, which is the most basic NEI computation. The second is for the performance path-based measure category, which is the most complex NEI computation. Details of NEI computations for all measure categories are provided in Appendix A of this report.

A. Example of cost differences – lighting measures

Table 6 provides an example of this process for lighting measures. The table includes all of the costs associated with the maintenance and repair of the fixtures over the 15-year lifetime defined in the TRM. For presentation purposes, these costs are aggregated to reflect the cost per fixture, assuming three lamps per fixture for fluorescent and a standard 3-lamp equivalent LED.

The table shows that the baseline T8 fixture requires lamp changes approximately every three years, and replacement fixtures every five years. However, LED fixtures require replacement only every ten years. Further, because LEDs are brighter than T8s (baseline), they require fewer fixtures to light a given area, reducing the labor and equipment costs associated with the lamp replacements. While this is not directly shown in Table 6, it is imbedded in the costs for bulb and fixture replacements. This table presumes that a larger number of fixtures and bulbs must be installed under a T8 scenario. For a detailed representation of the actual numbers affected by this issue, see Table 76 in Appendix A.

[9] http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-DRAFT-Electric-Gas-Energy-Efficiency-Plan.pdf.

We used differences such as these to calculate the NPV of the life-cycle costs and amortize to provide the average annual cost of owning each technology. The difference between the average annual amortized cost of the baseline and energy-efficient technologies reflect the NEI associated with that measure.

The Evaluation Team decided that we would assume that a fixture is replaced with the same kind of fixture during its first replacement in the analysis period. The second time it is replaced, it is replaced with an LED fixture to reflect the rapid adoption of LEDs in the marketplace. The grey areas in Table 6 represent this time period during which bulb changes are no longer necessary due to the LED being installed.

The values in red represent costs that occur during the analysis period but for which the entire value is not captured during the analysis period. For these items, we amortize the value of that cost over the lifetime of its utility, take a single year's worth of that amortized cost, and apply it to each year of the analysis period after its occurrence.

For example, in the table below a T8 fixture is presumed to be replaced with an LED fixture in year 10. LED fixtures last ten years, but there are only five years remaining in the analysis period. Therefore, we amortized the cost of the LED fixture over ten years to get $14 per year. Applying this $14 for each of the remaining five years accounts for the fact that the LED fixture will continue to be in-place and in operation after our analysis period (for five more years), and so much of its value remains.

We estimate NPV costs of $209 and $81 for a T8 and LED fixture, respectively, over an analysis period of 15 years. As a result, the estimated NEI for an efficient LED fixture is $129 relative to the baseline T8 fixture.

Table 6. Example of NPV of Costs for a Sampled Lighting Fixture Measure (Assuming 3 Lamps per Fixture) *

Type	Cost Category	Costs by Year (values measured in dollars)															Net Present Value		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Measure Totals		NEI
Baseline T8	Bulb Change	0.0	0.0	9.9	0.0	9.9	0.0	0.0	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	209	129
	Recycle	0.0	0.0	3.2	0.0	3.2	0.0	0.0	3.2	0.0	3.2	0.0	0.0	0.0	0.0	0.0	12.3		
	Fixture Replacement	0	0	0	0	89	0	0	0	0	14	14	14	14	14	14	168.1		
Efficient LED	Bulb Change	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81	
	Recycle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
	Fixture Replacement	0	0	0	0	0	0	0	0	0	14	14	14	14	14	14	80.9		

*Items shown in red reflect the annual cost of replacing the fixture with an LED fixture amortized over 10 years. For fixture replacement costs, we assume that T8 fixtures would be replaced in-kind in Year 5, but with an LED fixture in Year 10.

B. Example of cost differences – (Special Case) performance path-based measure category

This section describes our approach for estimating NEIs associated with the performance path-based (CDA project) measure. Estimating NEIs for the performance path-based measure category requires a different approach than that used for prescriptive or traditional custom measures. Custom-comprehensive projects are incentivized based on the extent to which the savings from the overall project (or collection of individual measures installed) performs relative to the applicable baseline or code (as modeled). This posed the following challenges for estimating NEIs for this measure category:

- Program tracking records for these projects report savings for the overall project under a single "Custom – Comprehensive Design Analysis (CDA)" measure, rather than reporting on the savings associated with the individual measures installed.
- The PAs' tracking records often do not report the individual measures installed; rather, they simply list the measures collectively and singly as "Comprehensive Design – Custom," one for electric and one for gas.
- It was possible for some projects reported singly under the "CDA – Gas" measure to also involve the installation of some electric measures, and vice-versa, even though savings were only reported for the fuel under which the project was reported. Without a database that linked projects under both the electric and gas programs, we could not readily determine whether these projects appeared in both the electric and gas databases, or identify them in the other database even if we expected them to be there.
- The total CDA project savings reported in the PA tracking data sometimes were not entirely consistent with the reported (or modeled) sum of the measure- or equipment-level savings estimated in the underlying documentation provided by the PAs (see Step 2 below).

In the text below, we first describe our general approach to estimating the NEIs for the performance path-based measure, which addressed the concerns mentioned above, then we provide an illustrative example of the NEI estimation process for this measure.

Our approach to estimating the NEIs for the performance path-based measure includes seven general steps:

1. *Select a sample of CDA projects* – We selected a sample of CDA projects (both electric and gas) from the 2013 program tracking data. This step is similar to the first step in estimating NEIs in other measure categories. However, it is important to note that these projects were listed in the tracking data under a single measure category (i.e., CDA – Electric or CDA – Gas) and did not indicate which individual measures or technical equipment were actually installed. The sample of projects drawn included 8 custom-comprehensive electric projects and 8 custom-comprehensive gas projects.
2. *Identify line items (the specific equipment) installed from paper documentation* – Because many of the records in the program tracking data did not provide detailed descriptions of the actual measures/technologies installed, we requested that the PAs provide the paper project documentation (e.g., Technical Assistance ("TA") studies) detailing the measures installed on each sampled project. The paper documentation contained the necessary information for identifying the measures/technologies installed, identifying the baseline, and estimating life-cycle costs. We used this information to estimate NEIs associated with each line item installed using the subsequent steps.
3. *Identify the baseline technologies* – Incentives for the performance path-based measure are based on the extent to which the new or renovated building or building system (as a whole) exceeds the efficiency required by code. Selecting the baseline was particularly challenging because it is not defined based on the equipment, but for the building or building system as a whole. For example, the baseline is typically

defined by the building simulation modeling assumptions as defined in ASHRAE 90.1 Appendix G. In this situation, the baseline for a centrifugal chiller installed in a CDA project could be a screw chiller or even several unitary rooftop units. We relied on the paper documentation to assist in defining the baseline for each installed measure or technology. In some cases, the program documentation clearly communicated how the baseline was defined. In cases where the baseline was different than that assumed for prescriptive measures by the TRM, we used the alternate baseline provided in the project paperwork. The chiller portion of the example found in Appendix A.2.1 provides one example of this. Where the PAs were not able to provide paper documentation, the Evaluation Team used its industry experience and, where appropriate, customer interviews, to determine which baseline code-compliant building system would mostly likely have been installed in the absence of the program.

4. *Estimate NEIs for each line item separately*[10] – Based upon the number, size, and other specifications for the actual equipment installed, we estimated the NPV of the life-cycle cost differences between the energy-efficient and baseline technologies for each line item identified in the paper documentation. Since many of the NEIs for these line items corresponded directly to their prescriptive counterparts, we used the same prescriptive-based NEI calculation formulas or specs developed previously. In this case, we added them to the set of NEI formulas for the performance-based measure. Further, we considered the combined operational cost impact of all line items for a sampled project, as some line items may have joint impacts on operational costs.

5. *Isolate NEIs to a single fuel type* – CDA projects reported in the electric and gas tracking data reported only savings associated with the respective fuel, and we were not able to readily determine whether the projects appeared in the other fuel type's program tracking records. Therefore, for each sampled project, we restricted the analysis to include NEIs associated with those line items that were relevant to the source program tracking database's fuel type. In other words, if the project record was identified from the gas program tracking database, we considered only line items that were relevant to gas measures (and gas savings). In our sample, none of the measures that affected both gas and electric savings (such as heat recovery or building shell) resulted in any quantifiable NEIs, so we did not have to determine how to split the NEIs between the electric and gas measures.

6. *Calculate the total NEI for each sampled project* – Next, we combined (summed) the NEIs for all of the individual measures/technologies or line items associated with the relevant fuel type.

7. *Calculate NEI / kWh or therm for the measure category* – Finally, we calculated the NEI per kWh or per therm factor across all sampled projects.

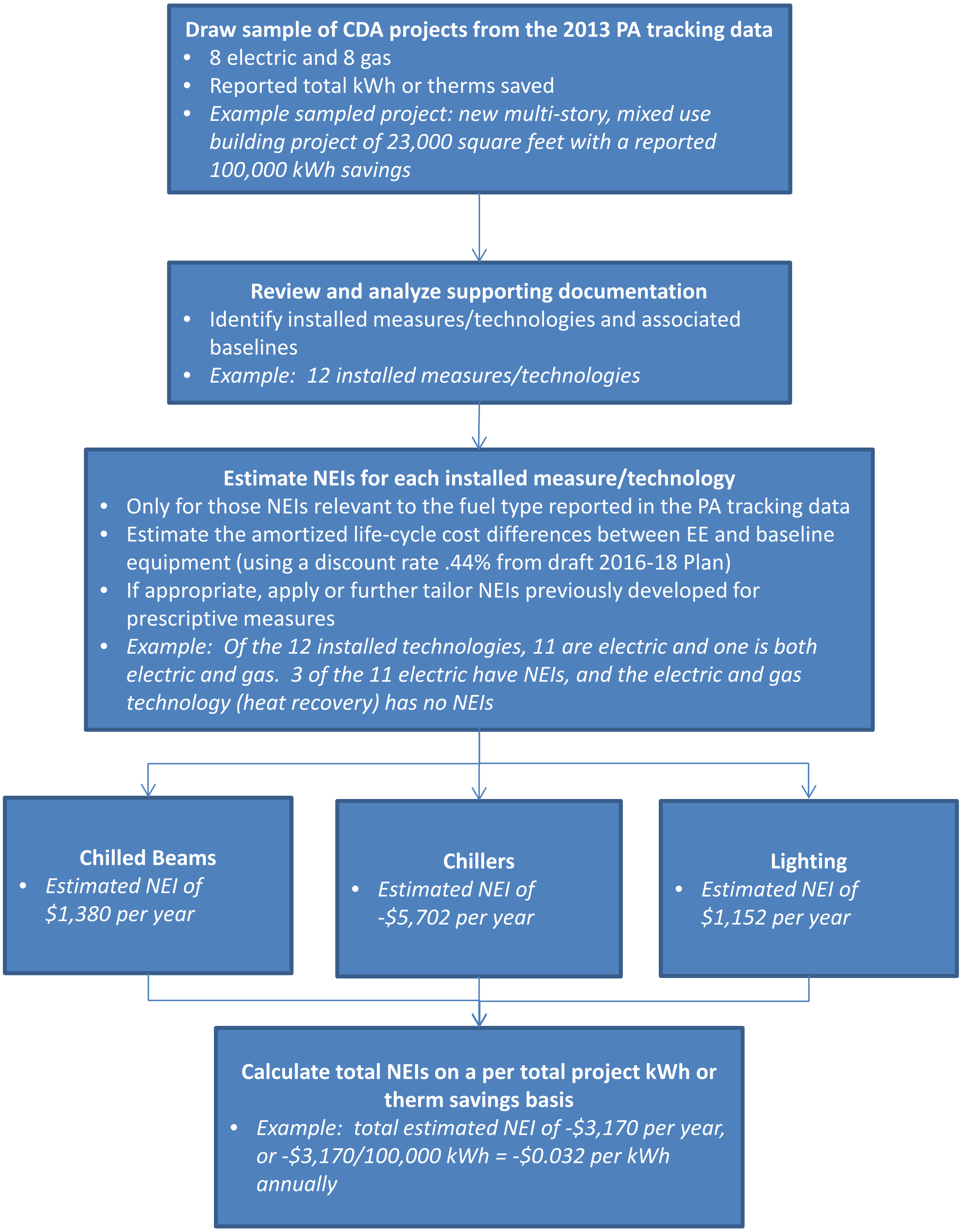
[10] Detailed descriptions of the NEI computations are provided in Appendix A.

C. Example of NEI Computations for Performance Path-Based Projects

Figure 3 illustrates how we calculated savings for one sample NC CDA project.

(Example) CDA project description: The building is an approximately 23,000-square-foot, multi-story, mixed-use building for which the program claimed approximately 100,000 kWh electric savings. The program did not claim any gas savings.

Figure 3. Process for Estimating NEIs Resulting from Performance Path-Based Measure



Section A.2.1 (Appendix A) provides additional detail on how we calculated savings for this sample NC CDA project.

3.6 ESTIMATE NEI PER UNIT OF ENERGY SAVINGS FACTOR FOR EACH MEASURE CATEGORY

Once we estimated the NEIs for each sampled measure (and the performance path-based measure category for each of the sampled CDA projects), the final step was to calculate the estimated NEI per unit of energy savings for the group of measures represented by our sample. This analysis was done at the sample BC measure level. We apply a weighting factor (w_{Aj}), which is the sampling case weight, for each sampled measure's estimated NEI to construct a "weighted" NEI for the population of measures in the respective BC or measure category. This factor is computed by dividing the total number of measures in a stratum (i.e., the total population of measures in the BC measure category – see Table 5) by the number of sampled measures in that stratum.

Similarly, the same factor is applied to the energy savings (kWh or therms) reported for each sampled measure. Finally, the sum of the total weighted NEIs is divided by the sum total weighted savings to derive the NEI per unit of energy savings factor, R_I, ($ per kWh or therm) for the stratum (e.g., BC measure category).

The NEI factor R_I was calculated using the following formula:

$$R_I = \frac{\sum_{j \varepsilon A} G_{Ij} w_{Aj}}{\sum_{j \varepsilon A} G_{Tj} w_{Aj}} .$$

Where:

> G_{Ij} = evaluation estimate of gross non energy impacts for sampled measure *j (or CDA project j)*
>
> G_{Tj} = tracking estimate of gross savings for sampled measure *j*
>
> w_{Aj} = sample expansion factor for individual measure j is equal to the total number of measures in the stratum for that measure divided by the number of sampled measures in the stratum.

The tables in Appendix A provide detailed calculations for each sample or BC measure category.

4. RESULTS

The estimated total annual value of NEIs for 2013 NC program participants that conducted true NC projects was $488,122 per year, across the total population of 957 true NC measures installed in 2013, including 13 electric projects and 10 gas projects listed under the single performance path-based CDA measure category.[11] Table 7 provides a breakout of estimated NEIs by project track.[12] The following discussion details the results of the engineering analysis. We first discuss the general results from the engineering analysis, and then discuss several special considerations in the analysis.

Table 7. Estimated Annual NEIs

Project Track	Annual NEI
Custom Electric	$ 89,261
Prescriptive Electric	$ 372,353
Custom Gas	$ (3,643)
Prescriptive Gas	$ 30,151
Total	**$ 488,122**

Table 8 and Table 9 present the estimated NEI factors (NEI/kWh or therm), whether that factor is statistically different from zero for each measure type, and average annual NEIs per measure (computed by multiplying the factor times the average annual savings per measure).

In most cases, we developed and report NEI estimates by measure and fuel for prescriptive and custom measures separately, with the exception of custom commercial kitchen. We present the prescriptive commercial kitchen NEI estimate for the Custom Food Service benefit cost category, since there were no custom commercial kitchen measures in the sample frame.

At the PAs' request, we have also broken out our NEI estimates by those expected for replacement (i.e., reduced replacement costs or the increased measure life of the more efficient equipment) and those expected for changes in operations and maintenance.

[11] The total annual value is calculated by summing the products of DNV GL's derived $NEI/unit of energy savings factor and the weighted 2013 annual energy savings for each sampled measure.

[12] The estimates shown in Table 7 are intended to illustrate the estimated magnitude of the total annual NEIs realized for true NC projects in 2013 because they include NEIs for some measure categories that did not meet the test for statistical significance.

Table 8. Electric NEI Results of Engineering Analysis by PA Benefit-Cost Category, Project Track, and Measure Type

Benefit- Cost Category	Sample Category	Average Annual NEI per Measure	Lifetime Replacement NEI/ kWh	Operations and Maintenance NEI/ kWh	Overall NEI/kWh	90% CI Low	90% CI High	Statistically Significant?	Source of Recommended NEI
Custom									
CHP	N/A	N/A	N/A	N/A	**N/A**	N/A	N/A	Not Studied	Not Sampled
Comprehensive Design	Comprehensive Design	$ 207	$ 0.002	$ (0.001)	**$ 0.001**	$ (0.007)	$ 0.009	Not Recommended	Custom Electric Comprehensive Design
Compressed Air	Compressed Air	$ 1,155	$ 0	$ 0.026	**$ 0.026**	$ 0.002	$ 0.050	b	Custom Compressed Air
Food Services	Commercial Kitchen	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0	Prescriptive Electric Commercial Kitchen
HVAC	HVAC	$ 330	$ 0.001	$ 0.001	**$ 0.001**	$ (0.002)	$ 0.005	a	Custom Electric HVAC/Heat Recovery
Lighting	Lighting	$ 320	$ 0.003	$ (0.000)	**$ 0.003**	$ (0.001)	$ 0.007	a	Custom Electric Lighting
Motors & VFD	Motors	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0	Custom Electric Motors
Other	Other	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0	Custom Electric Other
Process	Industrial Process	$ 3,990	$ 0.000	$ 0.013	**$ 0.013**	$ 0.004	$ 0.022	b	Custom Electric Industrial Process
Refrigeration	Refrigeration	$ 3,657	$ 0.003	$ 0.009	**$ 0.012**	$ 0.003	$ 0.021	b	Custom Electric Refrigeration
Overall	**Overall**	**$ 1,063**	**$ 0.002**	**$ 0.004**	**$ 0.006**	**$ 0.002**	**$ 0.009**	**c**	**Custom Electric Overall**
Prescriptive									
Compressed Air	Compressed Air	$ 1,717	$ 0	$ 0.038	**$ 0.038**	$ 0.033	$ 0.042	c	Prescriptive Compressed Air
Food Services	Commercial Kitchen	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0	Prescriptive Electric Commercial Kitchen
HVAC	HVAC	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0	Prescriptive Electric HVAC
Lighting	Lighting	$ 757	$ 0.014	$ 0.007	**$ 0.020**	$ 0.013	$ 0.028	c	Prescriptive Electric Lighting
Motors & VFD	Motors	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0	Prescriptive Electric Motors
Overall	**Overall**	**$ 522**	**$ 0.009**	**$ 0.006**	**$ 0.016**	**$ 0.010**	**$ 0.021**	**c**	**Prescriptive Electric Overall**

a: Recommended, but not well determined (.10 < p ≤ .50)

b: Recommended, statistically significant at 90% confidence (p ≤ .10)

c: Recommended, statistically significant at 99% confidence (p ≤ .01)

0: NEIs are determined to be negligible

Not Studied: No measures of this type in our sample

Not Recommended: p >.50

Table 9. Gas NEI Results of Engineering Analysis by PA Benefit-Cost Category, Project Track, and Measure Type

Benefit- Cost Category	Sample Category	Average Annual NEI per Measure	Lifetime Replacement NEI/ Therm	Operations and Maintenance NEI/ Therm	Overall NEI/Therm	90% CI Low	90% CI High	Statistically Significant?	Source of Recommended NEI
Custom									
Building Shell	Building Shell	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	0	Custom Gas Building Shell
Comprehensive Design	Comprehensive Design	$ (117)	$ 0	$ (0.004)	$ (0.004)	$ (0.008)	$ 0.000	a	Custom Gas Comprehensive Design
Condensing Boiler	Boilers	$ (73)	$ 0	$ (0.006)	$ (0.006)	$ (0.013)	$ 0.001	a	Custom Gas Boilers
Combination Boiler/Hot Water Heater	Boilers	$ (73)	$ 0	$ (0.006)	$ (0.006)	$ (0.013)	$ 0.001	a	Custom Gas Boilers
Condensing Unit Heater	Other Gas Heating	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	0	Custom Gas Other Gas Heating
Food Services	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Furnace	Other Gas Heating	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	0	Custom Gas Other Gas Heating
Heat Recovery	HVAC/ Heat Recovery	$ 4	$ 0	$ 0.000	$ 0.000	$ (0.000)	$ 0.001	a	Custom HVAC/ Heat Recovery
Heating	Other Gas Heating	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	0	Custom Gas Other Gas Heating
Hot Water	HVAC/ Heat Recovery	$ 4	$ 0	$ 0.000	$ 0.000	$ (0.000)	$ 0.001	a	Custom HVAC/ Heat Recovery
HVAC/ Heat Recovery	HVAC/ Heat Recovery	$ 4	$ 0	$ 0.000	$ 0.000	$ (0.000)	$ 0.001	a	Custom HVAC/ Heat Recovery
Infrared Heaters	Other Gas Heating	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	0	Custom Gas Other Gas Heating
Other	Other	$ (277)	$ 0	$ (0.032)	$ (0.032)	$ (0.092)	$ 0.029	a	Custom Gas Other
Process	Industrial Process	$ 72	$ 0	$ 0.007	$ 0.007	$ (0.011)	$ 0.025	Not Recommended	Custom Gas Industrial Process
Overall	**Overall**	**$ (83)**	**$ 0**	**$ (0.005)**	**$ (0.005)**	**$ (0.008)**	**$ (0.001)**	**b**	**Custom Gas Overall**
Prescriptive									
Combination Oven	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Condensing Boiler	Boilers	$ (137)	$ 0	$ (0.084)	$ (0.084)	$ (0.111)	$ (0.057)	c	Prescriptive Gas Boilers
Combination Boiler/Hot Water Heater	Boilers	$ (137)	$ 0	$ (0.084)	$ (0.084)	$ (0.111)	$ (0.057)	c	Prescriptive Gas Boilers
Condensing Unit Heater	Other Gas Heating	$ 17	$ 0	$ 0.053	$ 0.053	$ 0.043	$ 0.063	c	Prescriptive Gas Other Gas Heating
Convection Oven	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Conveyer Oven	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Food Services	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Fryer	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Furnace	Other Gas Heating	$ 17	$ 0	$ 0.053	$ 0.053	$ 0.043	$ 0.063	c	Prescriptive Gas Other Gas Heating
Griddle	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Heating	Other Gas Heating	$ 17	$ 0	$ 0.053	$ 0.053	$ 0.043	$ 0.063	c	Prescriptive Gas Other Gas Heating
Hot Water	HVAC/ Heat Recovery	$ 39	$ 0.327	$ (0.085)	$ 0.242	$ (0.174)	$ 0.657	a	Prescriptive Gas HVAC/ Heat Recovery
HVAC/ Heat Recovery	HVAC/ Heat Recovery	$ 39	$ 0.327	$ (0.085)	$ 0.242	$ (0.174)	$ 0.657	a	Prescriptive Gas HVAC/ Heat Recovery
Infrared Heaters	Other Gas Heating	$ 17	$ 0	$ 0.053	$ 0.053	$ 0.043	$ 0.063	c	Prescriptive Gas Other Gas Heating
Rack Oven	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Steamer	Commercial Kitchen	$ 2,732	$ 0	$ 3.399	$ 3.399	$ 0.961	$ 5.836	b	Prescriptive Gas Commercial Kitchen
Overall	**Overall**	**$ 260**	**$ 0.011**	**$ 0.224**	**$ 0.235**	**$ (0.007)**	**$ 0.477**	**a**	**Prescriptive Gas Overall**

a: Recommended, but not well determined (.10 < p ≤ .50)
b: Recommended, statistically significant at 90% confidence (p ≤ .10)
c: Recommended, statistically significant at 99% confidence (p ≤ .01)

0: NEIs are determined to be negligible
Not Recommended: p >.50

Treatment of the Comprehensive Design (CDA) measure. The CDA measure is an important part of the NC program and constitutes 18% of custom electric savings and 40% of custom gas savings. While a custom comprehensive project may contain both gas and electric saving technologies, we only consider the NEIs related to gas saving technologies for those projects recorded under the gas program, and NEIs related to electric saving technologies for those projects recorded under the electric program. There is one example of a project in our sample that is filed under both programs. However, this particular project did not result in any gas NEIs.

As shown in Table 8 and Table 9 we did not find statistically significant NEIs for the custom-comprehensive electric measures, but did find statistically significant NEIs for the custom-comprehensive gas measures. We recommend our estimate of -$.004/therm be used in the BC model for comprehensive gas measures, and do not recommend the NEI estimate for comprehensive electric measures be included.

NEIs for refined lighting categories. NEIs associated with lighting consist largely of differences in replacement and maintenance costs due to the longer lifetime of efficient bulbs. There were additional benefits with lamp replacement when fewer efficient lamps were needed to provide the same lumens as the baseline lamp. These cost savings were specific to the lamp type installed relative to the baseline standard efficiency T8 lamp. Therefore, it was relatively straightforward to estimate NEIs by lamp type as well. Table 10 shows the NEIs associated with the different lighting measure groups found within the program tracking data. While not currently used for benefit-cost reporting, these data could be valuable in promoting different lighting technologies and used in potential future analysis of NEIs associated with the upstream lighting program.

Of interest in this breakout is the relatively large difference in NEIs between identical measure types in the custom and prescriptive programs. Using the program data, we identified that custom lighting projects tend to replace few higher-wattage bulbs (e.g., metal halide) with an LED equivalent, whereas prescriptive projects tend to replace many lower wattage bulbs (T8) with an LED equivalent. This results in greater O&M savings per kWh for the prescriptive projects. Prescriptive T5 measures have the same replacement cycle as baseline T8s, but T5s have a higher price than T8s, resulting in negative NEIs even though they are brighter and require fewer lamps per lumen. Similarly, program-tracking data show that custom performance lighting consists largely of T5 fixtures, resulting in a negative NEI estimate.

Table 10. Lighting NEIs by Lamp Type

Measure Type	Measure Subtype	Ratio (NEI/kWh)	Statistically Significant?	2013 Weighted Amortized NEI
Custom Lighting	LEDs	$ 0.009	No	$2,525
	Other Lighting	$ 0.001	No	$497
	Performance Lighting	$ 0.004	No	$4,670
Prescriptive Lighting	LEDs	$ 0.036	Yes	$256,838
	Performance Lighting	$ 0.017	No	$38,398
	T5 Lighting	$ (0.001)	Yes	($3,693)
	High Bay LEDs	$ 0.048	Yes	$41,331
	T8 Lighting	$ -	N/A	

Comparison of NC NEI results to 2012 C&I Retrofit NEI results. As part of our analysis, we also compared the current results to the results calculated as part of the 2012 C&I Retrofit study. See Appendix C for the results of this comparison.

5. CONCLUSIONS, RECOMMENDATIONS AND CONSIDERATIONS, AND LIMITATIONS

5.1 CONCLUSIONS

Using the engineering approach discussed in this report, DNV GL was able to produce statistically significant NEI estimates for a range of measures sponsored by the Massachusetts New Construction Program. We have estimated total annual NEIs of $488,122 for the 957 identified true new construction measures installed in 2013, including 23 projects listed under the single performance path-based CDA measure category. These estimates include an overall NEI factor of $.006/kWh for custom electric measures, $.016/kWh for prescriptive electric measures, $-0.005/therm for custom gas measures, and $0.235/therm for prescriptive gas measures.

The engineering-based approach used for this evaluation allowed NEI estimates to be identified for specific measures within each of the PAs' benefit-cost measure categories. The breadth of measures within a specific category can result in low or insignificant overall NEIs for the category. Regardless, knowledge of the measure-specific NEIs can assist program planners and implementers in promoting measures that lead to higher overall benefits for customers.

5.2 RECOMMENDATIONS AND LIMITATIONS

Based on the results of this study, DNV GL provides the following recommendations and considerations:

Recommendation 1: The PAs should apply the recommended electric and gas NEIs presented in Table 2 and Table 3, respectively. These NEIs should be applied to the annual energy savings (kWh or therm) for each of the respective BC categories. Except performance based measures, NEIs reported here do not reflect interactive savings across measure groups. While not all of the recommended NEIs were statistically significant at a confidence interval of 90%, these estimates were based on rigorous quantification of life-cycle cost differences between energy-efficient and baseline efficiency measures. Our analysis demonstrates that there is substantial evidence to suggest that these cost differences should be anticipated for those measures that have a non-zero estimated NEI value. For measure categories for which we found too much variance among the sampled measures, we recommend a value of zero, as there was not sufficient evidence to suggest a positive or negative NEI.

Recommendation 2: Conduct further research to explore whether the NEIs estimated in this study can be applied to upstream program measures. The approach used in this analysis may be transferable to estimating NEIs for upstream programs, although additional research would be required to distinguish which measures sold through the upstream program are replace on failure/natural replacement or true new construction. In particular, NEIs for upstream lighting would largely consist of cost savings resulting from bulb replacements and waste disposal. Additional research is needed to examine whether NEIs associated with productivity or revenue increases are also relevant to upstream lighting measures. Future research could focus on how to apply the engineering-based analysis to relevant upstream measures.

Recommendation 3: Review the 2012 C&I Retrofit NEI results to assess whether the NEIs estimated in this study can be applied to replace on failure/natural replacement measures. While this study did not explicitly estimate NEIs associated with measures installed in replace on failure /natural replacement of existing equipment, many of the NEIs estimated in this study may also be applicable to such measures, especially since the PAs are taking steps to distinguish ROF measures in their tracking systems. However, we believe NEIs for ROF measures had already been evaluated and estimated as part of the 2012 Retrofit C&I NEI study. That study identified ROF measures by their free-ridership score, and their NEIs were adjusted to reflect the percentage of the NEI resulting from the measure being energy efficient based on a self-reported interview response. The Evaluation Team recommends that the PAs revisit the 2012 Retrofit study to assess the extent to which these ROF-measure NEIs can be isolated and subsequently updated or replaced by the NEI estimates provided in this study.

Consideration 1: The PAs should consider the advantages of adapting their benefit-cost models to accommodate more equipment- or technology-level NEI estimates. This NEI research was governed by how the PAs currently report NEI values at a more aggregate BC measure category level. However, the engineering approach taken for this analysis demonstrates that there are substantial differences in the positive and negative impacts associated with the different measure types and technologies within those categories. This consideration has two separate components:

1. **BC analysis and reporting.** The PAs currently track and report on costs and benefits in their BCA models at the measure category or end use level. Our analysis shows that NEIs for measures within those categories can vary considerably. In cases where a particular measure or technology has large negative NEIs and limited energy savings, the PAs may achieve greater economic return by shifting resources away from it. This would enable them to evaluate the optimal measure mix from a total benefit perspective.
2. **Program marketing.** The PAs could also consider focusing their marketing efforts and program support on measures with greater acceptance of efficient technologies. Further, identifying measures with negative NEIs will help the PAs isolate the potential barriers to their adoption. In cases where there are negative NEIs but large energy impacts, marketing staff could develop mitigation strategies to offset the potential increased O&M costs in order to increase their adoption.

Consideration 2: The PAs should consider collecting and recording more precise measure-level descriptions, including ex ante savings estimates, in their program tracking data for their custom CDA projects. Currently, only the paper documentation provided by two of the PAs contained sufficient measure-level information to estimate NEIs, and very little of this more detailed information is being recorded in the program tracking data. Further, recording such detailed measure-level data could help resolve any discrepancies between the paper documentation and the project savings ultimately recorded in the tracking data. This precluded us from developing an approach for estimating NEIs for performance path-based projects based on the relative mix of technologies. With improved data, it would be possible to construct more customized NEI estimates that could be adjusted depending upon the relative mix of the specific measures installed for a given CDA project. This may become increasingly important as the PAs' customers move toward greater reliance on performance path-based measures.

DNV GL identifies the following limitations in this study:

- The approach used to isolate true NC projects limited this study to those measures contained in the Dodge data or tax assessors' data.
- This study was focused on operational cost changes only. Because the measures installed were new construction, we could not justify including productivity or revenue increases, as our analysis did not find such changes would occur from an engineering perspective. Further research is required to explore whether there are additional sources of NEIs.

APPENDIX A: MEASURE-SPECIFIC NEI ESTIMATES

This appendix provides detailed descriptions and calculations of the NEIs estimated in this report, and their key sources of data and information.

- Section A.1 describes the CostLab software used to calculate NEIs in this study
- Section A.2 provides summary tables outlining the life-cycle costs and sources of NEIs for each measure category.

A.1 OVERVIEW OF COSTLAB SOFTWARE

CostLab is cost-estimation software produced by CBRE Whitestone that provides estimates for building O&M costs that many institutions and large businesses use to set their O&M budgets. It serves as the building maintenance industry's premier cost estimating source, and is even recommended by RS Means as a superior service for this purpose. While CostLab does not offer sufficient detail to differentiate between less and more efficient equipment, it does provide a good reference point for the O&M costs associated with the average piece of equipment or building system.

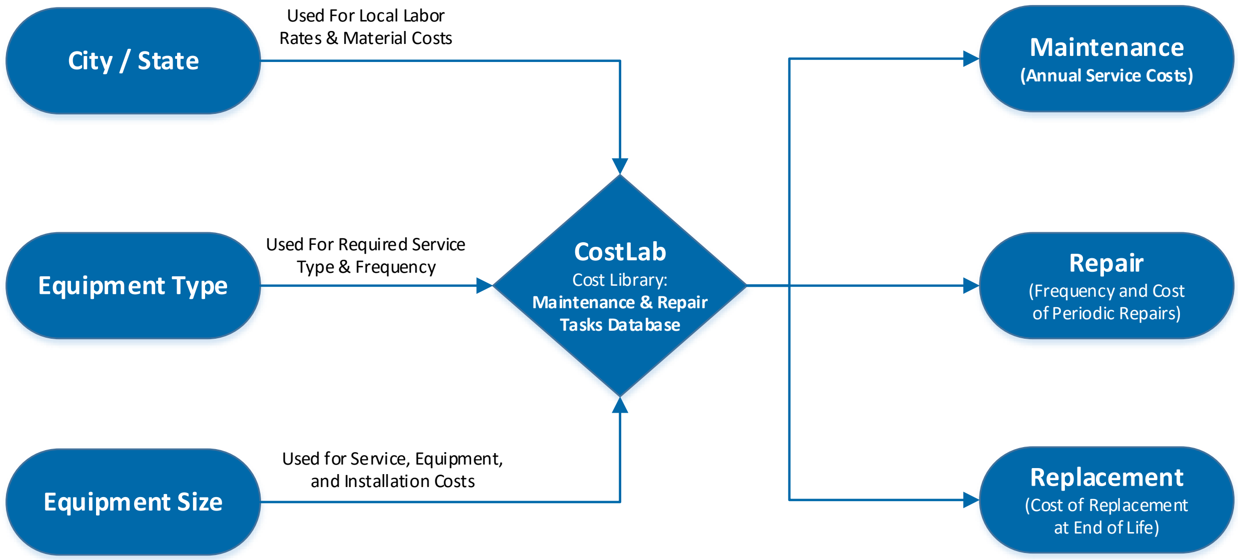
We used these estimates in many cases to establish the baseline costs of ownership to which we would compare our efficient equipment estimates. CostLab provides costs in terms of annual maintenance, periodic repair, and replacement costs.

The CostLab cost library itself is based on a number of sources gathered and updated over the course of many years. These sources include the following:

- Maintenance costs reported by the Department of Defense
- Maintenance costs reported by state building offices, including DCAMM in Massachusetts
- Feedback from CBRE Whitestone customers.

While it is possible to adjust CostLab to estimate costs for specific buildings, we simply used the estimates from the cost library database. As shown below in Figure 4, we input the geographical location for our analysis (we used Boston, Massachusetts) and the equipment type size, and CostLab provided us with maintenance, repair, and replacement costs, which we assigned to the baseline condition for some measures in our analysis.

Figure 4. Diagram of How We Used CostLab



While CostLab was useful for assigning values to some measures, other sources (including O&M manuals and interviews) provided more useful and detailed values for the majority of measures. We used CostLab for the measures and purposes shown in Table 11. CostLab data informed our thinking about other measures and inputs to other calculations, but we only used their data directly in these cases.

Table 11. Measures Incorporating CostLab Estimates

Category	Measure	CostLab Outputs Used
Gas HVAC	All Gas Heating Measures	Maintenance, Repair, and Replacement Costs
Electric HVAC	High-Efficiency Chillers	Cooling tower replacement cost.
Compressed Air	Zero Loss Condensate Drains	Hourly rate for air leak repairs
Lighting	All Lighting Measures	Maintenance and Repair costs

A.2 DISCUSSION AND ESTIMATION OF NEIS BY SAMPLE CATEGORY

This section provides detailed descriptions of the engineering analysis for each measure category. It is organized by fuel type (electric then gas), sample category, then BC measure category. For each BC measure category, the relevant equipment types are discussed (both baseline and energy efficiency); and, if applicable, NEIs are then estimated separately for custom and/or prescriptive applications.

Each measure category section contains a discussion of the following items:

- Baseline and efficient options
- Types of NEIs associated with the technology
- Costs of NEIs when they occur
- The schedule in which NEIs occur.

One consideration to keep in mind when reading this material is that we only report costs, which differ between baseline and efficient options. Maintenance, repair, and replacement items that cost the same amount and occur at the same frequency for both baseline and efficient options are ignored in tables and charts, though they may be discussed in text.

While the following sections are broken apart by fuel type (gas vs. electric), NEIs are not driven by the fuel type used but by other considerations. When NEIs for a piece of electric equipment are the same as for the natural gas version of that equipment, we recorded our findings under one fuel's section and referred to those findings from the other fuel's section.

In the data provided by the PAs for true new construction projects, there were not any combined heat and power projects (CHP). These projects are likely to have significant non-energy impacts, but were not sampled and therefore no estimate of NEIs for CHP was made.

A.2.1 Electric – Comprehensive Design

The Mass Save® program defines Comprehensive Design as follows:

> *For new commercial construction buildings over 100,000 square feet the Comprehensive Design Approach (CDA) is available. CDA is a Custom approach designed to maximize electric and gas energy savings and financial incentives for the project. It is a whole-building systems approach with interaction of mechanical and electrical systems, including the building envelope design, for building optimization in energy-saving performance.*[13]

CDA requires a specific analysis of multiple systems integrated into a design. The analysis usually involves an energy model of some kind. The NEIs relating to CDA combine multiple technologies. Analyzing the non-energy impact involves combining many technologies across the utility incentive program.

The Electric - Comprehensive Design measure category includes a wide variety of measures, but the following make up the majority of energy savings. See the applicable sections for estimates of NEIs for these specific measures, which are combined to estimate NEIs for specific projects.

[13] http://www.masssave.com.

Lighting

- Performance Lighting
- Controls
- LEDs

Electric HVAC

- Controls
- Chillers
- Unitary Cooling
- Chilled Beams

Motors

- Variable-frequency drives (VFDs)
- Electrically commutated motors (ECMs)

Building Shell

- Insulation & Air Sealing
- Windows.

Calculation Approach for Sample NC CDA Measure—Continued

Section 3.5.1 of this report provided an overview of how we calculated savings for one sample NC CDA project. In the sample project, the building is an approximately 23,000-square-foot, multi-story, mixed-use building for which the program claimed approximately 100,000 in electric kWh savings. The program did not claim any gas savings.

Here we provide greater detail regarding the calculation for that sample measure. Table 12 shows the baseline system and proposed system for each line item. Table 13, Table 14, and Table 15 present example NPV calculations. Table 16 and Table 17 summarize the NEIs for this CDA measure.

As explained in Section 3.5.1, we restricted this analysis to include NEIs associated with those line items relevant to electric savings. In this example, there was one measure that affected both electric and gas savings (HVAC/Heat Recovery), but this measure does not have any quantifiable NEIs for which we would have had to allocate between electric and gas.

Table 12. Detailed Account of Line-Items Included in Sampled Measure

Category	Measure Name	Gas / Electric	Baseline System	Proposed System
HVAC	Controls	Electric	No DDC system	DDC controls
HVAC	Chilled Beams	Electric	Typical air handling system	Chilled beams with 100% outside air supply for ventilation only
HVAC	Controls	Electric	Typical ventilation system	CO_2 sensor Aircuity system
HVAC	Controls	Electric	No reset	Static pressure reset for VFD energy recovery fans
HVAC	Heat Recovery	Both	No energy recovery	Total exhaust energy recovery. 76% effective
HVAC	Chillers	Electric	DX cooling	Water-cooled VFD chiller with free cooling
HVAC	Fans	Electric	Standard air handlers	Variable speed AHUs with "active induction," oversized steam coils, enthalpy economizers, and airfoil fans
Lighting	Performance	Electric	Code-minimum for labs & offices	10% better than code. Mostly fluorescent. Few LEDs
Lighting	Controls	Electric	No daylighting control	On-off daylighting control in private offices and conference rooms
Lighting	Controls	Electric	Occupancy sensors in required areas	Occupancy sensors in additional areas (doesn't say how many)
Motors	Fans	Electric	Standard VAV boxes	ECM VAV boxes
Motors	Other	Electric	Standard motors in AHUs	NEMA premium motors in AHUs

This measure had NEIs derived from the chilled beam, chiller, and performance lighting line items. The sections that follow discuss the details of the computation for NEIs associated with each of these line items.

- *Chilled Beams* – NEIs for chilled beams consisted of maintenance savings only. We calculated the NEIs for chilled beams using the following NPV table over a 15-year analysis period, with the value calculated per each fan coil unit, or each 1000 ft^2, for a total savings of \$869 x (23,000 ft^2 / 1000 ft^2) = \$19,780 over the lifetime, or \$1,035 if amortized per year. This amortization is not shown in the table below, but can be seen in Table 63 later in the report.

Table 13. Chilled Beams NEI Table

Cate-gory	Type	Cost Category	Costs by Year (values measured in dollars)																				Net Present Value		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
Chilled Beam	Fan Coil	Maintenance	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	0	0	0	0	0	869	869	869
		Repair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Chilled Beam	Maintenance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		Repair	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

- *Chillers* – This particular chiller project had an unusual baseline-installed combination. The baseline chiller for this site was an air-cooled screw chiller, and the newly installed equipment was a water-cooled screw chiller. We calculated the NEIs over a 20-year analysis period. The comparison between these two options is shown below, for a total NEI of $-61,231 over the lifetime, or $-3,205 if amortized per year. Note that the red text refers to items for which the lifetime of the replacement equipment extended beyond the analysis period. In these cases, the capital cost (for replacement) was amortized over the equipment life and the annualized cost was included for years within the analysis period.

Table 14. Chiller NEI Table

Cate-gory	Type	Cost Category	Costs by Year (values measured in dollars)																				Net Present Value		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
Air Cooled	Screw Chiller	Maintenance	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	19716	43214	-61231
		Compressors	0	0	0	0	2969	0	0	0	0	2969	0	0	0	0	0	0	0	0	0	602	6297		
		Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3096	3096	3096	3096	3096	3096	17201		
Water Cooled	Screw Chiller	Maintenance	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	19716	32336	
		Compressors	0	0	0	0	1666	0	0	0	0	1666	0	0	0	0	1666	0	0	0	0	338	5093		
		Condenser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1355	1355	1355	1355	1355	1355	7526		
Cooling Tower Add	If WC vs. AC	Maintenance	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	3208	61289	72110	
		Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1947	1947	1947	1947	1947	1947	10821		

- *Performance Lighting* – This building had a watts per ft^2 value that was 10% better than code, or approximately 0.90 watts/ft^2, per ASHRAE 90.1 2007. In this case, we assumed that the majority of the building was lit by high-performance lighting like T5 fluorescent lights, assuming a 3-lamp fixture every 80 ft^2. We calculated the NEIs over a 15-year analysis period. The comparison between these two options is shown below, for a total NEI of 23,000 ft^2 / 80 ft^2 x ($-4) = $-1,150 over the lifetime, or -$79 if amortized per year. Note that the red text refers to items for which the lifetime of the replacement equipment extended beyond the analysis period. In these cases, the capital cost (for replacement) was amortized over the equipment life and the annualized cost was included for years within the analysis period.

Table 15. Lighting NEI Table

Type	Cost Category	Costs by Year (values measured in dollars)															Net Present Value		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Measure Totals		NEI
Baseline T8	Bulb Change	0.0	0.0	9.9	0.0	9.9	0.0	0.0	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	209	-4
	Recycle	0.0	0.0	3.2	0.0	3.2	0.0	0.0	3.2	0.0	3.2	0.0	0.0	0.0	0.0	0.0	12.3		
	Fixture Replacement	0	0	0	0	89	0	0	0	0	14	14	14	14	14	14	168.1		
Efficient T5	Bulb Change	0	0	12	0	12	0	0	12	0	0	0	0	0	0.0	0.0	35.2	213	
	Recycle	0	0.0	2.9	0.0	2.9	0.0	0.0	2.9	0.0	2.9	0.0	0.0	0.0	0.0	0.0	11.2		
	Incentive	0	0	0	0	-25	0	0	0	0	0	0	0	0	0	0	-24.5		
	Fixture Replacement	0	0	0	0	113	0	0	0	0	14	14	14	14	14	14	191.6		

The total NEI savings for this comprehensive design measure was the sum of the NEIs for each line item, or $1,035 + ($-3,205) + ($-79) = $-2,249 per year.

Table 16 below provides a detailed breakdown of NEIs for each measure rolled up within each CDA project. The "Total Annual NEI" column provides a weighted estimate of annual NEIs for each measure. Table 17 provides an overall summary of the CDA sample category.

Table 16. NEIs by Electric CDA Project

CDA Project	Measure Type/ Technology	Custom Average Annual NEI	Custom Total Weighted Annual NEI	Custom Sampled Measures
5	Building Shell	$ -	$ -	2
5	HVAC	$ -	$ -	5
5	**Overall**	**$ -**	**$ -**	**7**
6	HVAC	$ (356.95)	$ (2,900.24)	5
6	Lighting	$ -	$ -	2
6	Motors	$ -	$ -	1
6	**Overall**	**$ (223.10)**	**$ (2,900.24)**	**8**
10	HVAC	$ (444.74)	$ (5,058.88)	7
10	Lighting	$ (27.13)	$ (132.24)	3
10	Motors	$ -	$ -	2
10	**Overall**	**$ (266.21)**	**$ (5,191.12)**	**12**
13	Building Shell	$ -	$ -	1
13	HVAC	$ 2,393.40	$11,667.82	3
13	Lighting	$ (169.83)	$ (551.95)	2
13	Motors	$ -	$ -	1
13	**Overall**	**$ 760.06**	**$11,115.87**	**7**
14	Building Shell	$ -	$ -	1
14	HVAC	$ -	$ -	7
14	Lighting	$ (409.54)	$ (1,331.01)	2
14	Motors	$ -	$ -	3
14	**Overall**	**$ (63.01)**	**$ (1,331.01)**	**13**
22	HVAC	$ 293.81	$ 1,909.76	4
22	Lighting	$ (221.14)	$ (359.34)	1
22	Motors	$ -	$ -	1
22	**Overall**	**$ 159.02**	**$ 1,550.42**	**6**
24	HVAC	$ 15.00	$ 97.50	4
24	Lighting	$ (84.92)	$ (275.98)	2
24	Motors	$ -	$ -	1
24	**Overall**	**$ (15.69)**	**$ (178.48)**	**7**
39	HVAC	$ -	$ -	1
39	Lighting	$ (115.06)	$ (373.95)	2
39	Motors	$ -	$ -	1
39	**Overall**	**$ (57.53)**	**$ (373.95)**	**4**
Overall Weighted Electric CDA		**$ 207**	**$ 2,691**	**8**

Table 17. Summary of NEIs for CDA Projects

	Custom
Sampled Measures (a)	8
Average NEI per Sample Measure	$ 207
Sample Total NEIs (b)	$ 1,656
Sample Total kWh Savings (c)	1,797,427
NEI/kWH (d = b / c)	$ 0.001
90% CI Low	$ (0.007)
90% CI High	$ 0.009
p-value	0.84
Population Measures (2013) (e)	13
Weighted Population Savings kWh (2013) (f = c * (e / a))	2,920,819
Total Estimated Population NEI (g = d * f)	$ 2,691

A.2.2 Electric – Building Shell

As shown in Table 5, the population of building shell measures with electric savings included one custom and zero prescriptive measures installed in 2013. In addition, four of the eight electric custom comprehensive design (CDA) projects we sampled included the installation of at least one building shell measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least two types of building shell measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following two types of building shell measures or technologies are considered further in our NEI analysis:

- Insulation & Air Sealing
- High-performance Windows.

The following sections summarize the NEI estimates for each measure type.

Insulation and air sealing

The construction of the building enclosure—especially its air and vapor permeability, color, levels of insulation, resistance to air leakage, and thermal mass—has a significant impact on energy efficiency and occupant comfort. The building enclosure also affects acoustic comfort as it can attenuate site and traffic noise. Selecting materials for the construction of the building enclosure affects resource efficiency, including transport energy, the volume and type of raw materials that must be extracted from the earth, the energy required for manufacturing, and packaging.

It is important to provide an exterior weather barrier with drainage plane to prevent moisture from entering construction cavities. It is also important to design a wall, roof, and foundations system, so that if water enters, it can dry out. Wet or damp construction cavities, attics, and plenums are a major source of mold and can contribute significantly to indoor air quality (IAQ) problems. In addition, moisture can damage the structure and degrade the performance of insulation, increasing energy and operating costs. Many IAQ complaints are related to leaky roofs that have resulted in the growth of mold in a plenum, wall system, attic space, or in part of a foundation space such as a crawl space or utility trench.

Water vapor can enter construction cavities through a process of moisture migration. Moisture migrates from the warm and humid side of the construction assembly to the cold dry side of the construction assembly. The vapor cools as it moves through the wall and, as it reaches dew point conditions, may condense into water molecules that can accumulate to cause damage and create mold. Moisture also follows air leakage through a construction assembly. In addition to correctly installing a vapor retarder, it is important to provide adequate ventilation to dry spaces where moisture can build up. Most building codes require that attics and crawl spaces be ventilated, and some require a minimum one-inch clear airspace above the insulation for ventilation of vaulted ceilings. Even the wall cavity may need to be ventilated in extreme climates.[14]

With this in mind, building envelopes are critical aspects to construction. However, NEIs are difficult to quantify, as the only time that maintenance, repair, or replacement occur is if the building envelope fails due to poor construction. The interviews with manufacturers, contractors, and customers all revealed that nobody expects any NEIs from added insulation or air sealing.

The following table shows the characteristics of the baseline envelope requirements from ASHRAE 90.1 2007. Although exceeding these values offers energy savings, there is no NEI related to the increase.

[14] http://apps1.eere.energy.gov/buildings/publications/pdfs/energysmartschools/nationalbestpracticesmanual31545.pdf.

Table 18. Building Shell ASHRAE 90.1 Guidelines

ASHRAE 90.1 2007—Climate Zone 6		
Prescriptive Fenestration Requirements	**Maximum U Factor**	**R-Value**
Non-metal frame	0.35	2.9
Curtain wall/storefront	0.4	2.5
Entrance door	0.8	1.3
All other metal frame	0.55	1.8
Prescriptive Shell Requirements	**Maximum U Factor**	**R-Value**
Roofs		
Insulation entirely above deck	U-0.048	R-20.0 c.i.
Attic and other	U-0.027	R-38.0
Walls, above-grade		
Mass	U-0.08	R-13.3 c.i.
Steel-framed	U-0.064	R-13+R-7.5 c.i.
Walls, below-grade		
Below-grade wall	C-0.119	R-7.5 c.i.
Floors		
Mass	U-0.064	R-12.5 c.i.

High-performance windows

One common new construction practice in Massachusetts is a curtain wall design instead of the standard steel and reinforced concrete system. One major advantage of the curtain wall is that it can be constructed from much lighter materials (like glass), which allows for the filtration of natural light into the building. It has been reported that a curtain wall design can have additional maintenance to contain air infiltration and water leaks. However, this depends greatly on the quality of construction, and quantifying it is difficult and specific to each building.

Whether a new construction utilizes a curtain wall or a more standard system, the code dictates the glass and assembly U-Value. The interviews resulted in no quantifiable NEIs based strictly on purchasing a window with a more effective U-Value.

Table 19. Building Fenestration ASHRAE 90.1 Guidelines

ASHRAE 90.1 2007—Climate Zone 6		
Prescriptive Fenestration Requirements	**Max U Factor**	**Solar Heat Gain Coefficient**
Non-metal frame	0.35	0.25
Curtain wall/storefront	0.45	
Entrance door	0.8	

Electric – building shell summary

The following tables summarize the NEIs we calculated for the electric building-shell sample categories, as well as the total population of electric building shell measures installed in 2013. We estimated zero NEIs for the one measure in the population.

Table 20. NEI Estimates for Measures in Electric Building Shell Sample Categories

	Custom		
Measure Type/ Technology	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Building Shell	$ -	$ -	1
Overall	**$ -**	**$ -**	**1**

Table 21. Overall NEI Estimates for Electric Building Shell Sample Categories

	Custom
Sampled Measures (a)	1
Average NEI per Sample Measure	$ -
Sample Total NEIs (b)	$ -
Sample Total kWh Savings (c)	80,240
NEI/kWH (d = b / c)	$ -
90% CI Low	$ -
90% CI High	$ -
p-value	0.00
Population Measures (2013) (e)	1
Weighted Population Savings kWh (2013) (f = c * (e / a))	80,240
Total Estimated Population NEI (g = d * f)	$ -

A.2.3 Electric – Commercial Kitchen

Commercial kitchen equipment NEIs are based on the equipment taking less time to maintain and clean (fewer labor hours), requiring less cleaning product, or requiring less cooking medium (water or oil).

As shown in Table 5, from the population of commercial kitchen measures[15] with electric savings (zero custom and one prescriptive) installed in 2013, we drew a sample of one prescriptive measure to characterize the types of technologies deployed in NC and their associated NEIs. None of the eight custom comprehensive design (CDA) projects we sampled included the installation of any commercial kitchen measures.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least three types of commercial kitchen measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following three types of commercial kitchen measures or technologies are considered further in our NEI analysis:

- Commercial Ovens
- Commercial Steam Cookers
- Commercial Fryers.

The following sections summarize the NEI estimates for each measure type.

Commercial ovens

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 22. Summary of Efficient and Baseline Options for Commercial Ovens[16]

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Annual operation hours[17]	Convection Oven: 3,130 Combination Oven: 3,756	Convection Oven: 3,130 Combination Oven: 3,756	**Maintenance**: Efficient combination ovens reduce water use by 43,800 gallons per year, saving associated water and wastewater costs
Equipment Life	12 years	12 years	

No repair, maintenance, or replacement NEIs were determined to result from replacement of commercial convection ovens.

[15] Commercial kitchen are a sample category not a benefit-cost category.
[16] No conveyor ovens were sampled as part of this analysis.
[17] Based on TRM assumption of 6 day/week operation, or 313 days/year. Convection ovens are assumed to operate 10 hours/day, and combination ovens are assumed to operate 12 hours/day.

NEIs associated with this measure are as follows:

- *Water use* – Convection ovens were not found to have reductions in maintenance costs. Efficient combination ovens reduced water use over the baseline technology, with an associated reduction in costs.[18] Consistent with the TRM, all water is assumed to end its life as wastewater (rather than evaporated), such that wastewater costs decrease with water savings.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 23. Cost Schedule for Commercial Ovens

Year	Combination		Convection	
	Baseline	Efficient	Baseline	Efficient
1	W			
2	W			
3	W			
4	W			
5	W			
6	W			
7	W			
8	W			
9	W			
10	W			
11	W			
12	W			

W=Water Use

The table below shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 24. Cost Breakdown for Commercial Ovens (Price For Each Occurrence Shown Above)

Size Category	Baseline	Efficient
	Water Use	Water Use
Full size combination oven	$108	-
Full size	-	-

[18] http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php.

convection oven		

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 25. Lifetime and Annualized Costs for Commercial Ovens

Category	Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
	Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
Combination	$ 1,265	$ -	$ -	$ 1,265	$ -	$ -	$ -	$ -	$ 1,265	$ 108
Convection	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Commercial steam cookers

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 26. Summary of Efficient and Baseline Options for Commercial Steam Cookers

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Steam Generator	Boilerless	**Maintenance**: Efficient commercial steamers reduce water use. Each efficient steamer requires more filter replacements and less de-liming maintenance.
Percentage of Time in Constant Steam Mode	40%	40%	
Average Water Consumption Rate (gal/hr.)	40	3	
Idle Energy Electric (kW)	1.2	0.4	
Equipment Life	12 years	12 years	

NEIs associated with this measure are as follows:

- *Maintenance* – Efficient commercial steamers reduce water use over the baseline technology, with an associated reduction in costs.[19] Consistent with the TRM, all water is assumed to end its life as wastewater (rather than evaporated), such that wastewater costs decrease with water savings. Each efficient steamer contains two water filters not included in baseline equipment; these filters are replaced once quarterly for a total of eight filter replacements per year. Efficient steamers require de-liming maintenance once quarterly rather than the once-monthly service required by baseline equipment, resulting in a decrease in both chemical cost and internal staff maintenance time. All of these maintenance requirement changes were corroborated by customer interviews.

[19] http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 27. Cost Schedule for Commercial Steam Cookers

Year	Baseline	Efficient
1	M	M
2	M	M
3	M	M
4	M	M
5	M	M
6	M	M
7	M	M
8	M	M
9	M	M
10	M	M
11	M	M
12	M	M

M=Maintenance

The table below shows the prices associated with each cost listed above. Each value in the table represents a single letter above.

Table 28. Cost Breakdown for Commercial Steam Cookers (Price for Each Occurrence Shown Above)

Size Category	Baseline Maintenance	Efficient Maintenance
All	$966	$3788

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 29. Lifetime and Annualized Costs for Commercial Steam Cookers

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 11,266	$ -	$ -	$ 11,266	$ 44,185	$ -	$ -	$ 44,185	$ (32,919)	$ (2,822)

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Commercial fryers

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 30. Summary of Efficient and Baseline Options for Commercial Fryers

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Shortening Capacity	65	65	**Maintenance**: Baseline requires increased fryer oil replacement, filter pads, filter powder, oil filtering, and annual contractor maintenance time.
Equipment Life	12 years	12 years	

NEIs associated with this measure are as follows:

- *Maintenance* – Baseline technology requires higher maintenance costs relative to efficient equipment, including increased fryer oil replacement, filter pads, filter powder, internal maintenance time for oil filtering, and annual contractor maintenance time. Filters are not needed for the efficient equipment, and an estimated 30 minute (minimum) oil filtering operation is reduced from once every two days to once every two months, per customer interviews. The largest proportion of maintenance savings results from average annualized savings of fryer oil replacement due to the self-cleaning operation of the efficient unit. Because burned particles do not contaminate the oil, fryer oil life is greatly increased. Finally, external contractor maintenance time is reduced from once annually to once every three years.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 31. Cost Schedule for Commercial Fryers

Year	Baseline	Efficient
1	M	M
2	M	M
3	M	M
4	M	M
5	M	M
6	M	M
7	M	M
8	M	M
9	M	M
10	M	M
11	M	M
12	M	M

M=Maintenance

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 32. Cost Breakdown for Commercial Fryers (Price For Each Occurrence Shown Above)

Size Category	Baseline Maintenance	Efficient Maintenance
All	$6,983	$130

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 33. Lifetime and Annualized Costs for Commercial Fryers

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 81,444	$ -	$ -	$ 81,444	$ 1,513	$ -	$ -	$ 1,513	$ 79,931	$ 6,853

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Electric – commercial kitchen summary

The following tables summarize the NEIs we calculated for the electric commercial kitchen sample categories, as well as the total population of electric commercial kitchen measures installed in 2013.

Table 34. NEI Estimates for Measures in Electric Commercial Kitchen Sample Categories

Measure Type/ Technology	Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Convection Oven	$ -	$ -	1
Combination Oven	$ -	$ -	0
Steamer	$ -	$ -	0
Fryer	$ -	$ -	0
Overall	**$ -**	**$ -**	**1**

Table 35. Overall NEI Estimates for Electric Commercial Kitchen Sample Categories

	Prescriptive
Sampled Measures (a)	1
Average NEI per Sample Measure	$ -
Sample Total NEIs (b)	$ -
Sample Total kWh Savings (c)	1,364
NEI/kWH (d = b / c)	$ -
90% CI Low	$ -
90% CI High	$ -
p-value	0.00
Population Measures (2013) (e)	1
Weighted Population Savings kWh (2013) (f = c * (e / a))	1,364
Total Estimated Population NEI (g = d * f)	$ -

A.2.4 Electric – Compressed Air

Compressed air systems are used primarily in manufacturing and auto repair as a critical tool needed to operate many processes. The industrial compressed air system is the "workhorse" of the industrial process as it is required to make many factories operate.

As shown in Table 5, from the population of compressed air measures (5 custom and 23 prescriptive) installed in 2013, we drew a sample of 4 custom and 10 prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. We were only able to complete NEI calculations for 3 of the 5 custom measures. None of the eight electric custom CDA projects we sampled included the installation of at least one compressed air measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the CDA projects we sampled, we identified four types of compressed air measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following four types of compressed air measures or technologies are considered further in our NEI analysis:

- High-Efficiency Air Compressors
- Refrigerant Air Dryers
- Low-Pressure Drop Filters
- Zero Loss Condensate Drains.

The following subsections describe and present the analytical approach and results of the NEIs estimated for each of these four compressed air measure types or technologies. At the end of this section, we summarize the NEIs estimated across these four measure types/technologies that are used to characterize and quantify the NEI for the entire compressed air sample category, as well as the total population of compressed air measures installed in 2013.

High efficiency air compressors

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 36. Summary of Efficient and Baseline Options for High-Efficiency Air Compressors

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Modulating Compressor (Reciprocating)[20]	Rotary Screw	**Size:** HP can be reduced **Repair/Replacement:** Designed to last the life of the system as opposed to periodic rebuilds (every 5 years) **Maintenance:** Oil changes every 3 years as opposed to 3 times per year
Control	Across the line motor control	VFD, Load/No Load or Variable Displacement controlled	
Lubrication	Single or double stage	Oil flooded	
Blow-Down Valve	Blow down valve	No Blow Down Valve	
Equipment Life	15 years	15 years	

NEIs associated with this measure are as follows:

- *Repair/replacement* – All compressors require either replacement or rebuilding. Compressors can be rebuilt many times depending on the conditions of the location (excessive heat, moisture, dust, etc.) and the process use. The interview phase involved conversations with very experienced building engineers. Many of them discussed the lifespan of compressors. They were able to keep compressors running for over 30 years, albeit very inefficiently and well past the useful life. However, this shows that if maintained well, rebuilding a compressor and replacing worn parts results in a very extended lifespan. Reciprocating compressors have fewer moving parts than screw compressors, meaning rebuilding is easier. Reciprocals require rebuilding or replacement every 10,000 hours or around every 5 years. The more efficient rotary screw compressors, on the other hand, last between 20,000 and 25,000 hours (more than 10 years) before requiring similar service or replacement.[21]

- *Maintenance* – Oil changes are the most common maintenance item in compressors. A reciprocating air compressor generally requires oil changes every 3 to 12 months with the assumption that most owners wait a little longer to perform the maintenance than a manufacturer recommends. It was found that most buildings changed the oil three times per year on reciprocal units. On the other hand, for the more efficient rotary screw compressors, Portland Compressor[22] recommends oil should be

[20] The TRM doesn't specifically state that a reciprocating compressor is the baseline. It doesn't mention a compressor type at all. In practical application, a reciprocating compressor is usually seen as the low-cost option.
[21] http://www.plantengineering.com/single-article/rotary-screw-or-reciprocating-air-compressors-which-one-is-right/1563ecc5630401b2d6575680d867854a.html.
[22] Conversation with a service engineer at Portland Compressor.

changed about every 7,000 to 8,000 hours (about every 3 to 4 years). Other maintenance items performed during oil changes are filter cleaning or replacing, oil separator inspection, and general unit cleaning.

Based on our analysis of the NEIs discussed above, the following tables show the schedule and breakdown of costs associated with the baseline and efficient options for this measure/technology. In summary, the key assumptions or inputs used in CostLab included:

- Reciprocating compressors (baseline) are rebuilt every 5 years, rotary screw compressors (efficient option) are not rebuilt or replaced during the analysis period
- 15-year analysis period
- Reciprocating compressors (baseline) are maintained (oil changes) three times per year; rotary screw compressors (efficient option) are maintained once every three years
- Labor assumptions/inputs
- Other assumptions/inputs.

Table 37. Cost Schedule for High-Efficiency Air Compressors

Year	Baseline	Efficient
1	M	
2	M	
3	M	M
4	M	
5	M, R	
6	M	M
7	M	
8	M	
9	M	M
10	M, R	
11	M	
12	M	M
13	M	
14	M	
15	M	M

M=Maintain: oil changes
R=Repair/Replacement: rebuild compressor

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 38. Cost Breakdown (Price for Each Occurrence Shown Above)

Size Category	Baseline		Efficient	
	Maintain	Repair	Maintain	Repair
1-24 HP	$410	$3,000	$450	n/a
25-50 HP	$410	$10,000	$450	n/a
>50 HP	$410	$12,000	$450	n/a

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 39. Lifetime and Annualized Costs for High-Efficiency Air Compressors

Category	Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
	Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
1-24 HP	$ 5,975	$ 5,806	$ -	$ 11,781	$ 2,163	$ -	$ -	$ 2,163	$ 9,618	$ 664
25-50 HP	$ 5,975	$ 19,353	$ -	$ 25,328	$ 2,163	$ -	$ -	$ 2,163	$ 23,165	$ 1,599
>50 HP	$ 5,975	$ 23,224	$ -	$ 29,199	$ 2,163	$ -	$ -	$ 2,163	$ 27,036	$ 1,866

* Reflects the total NPV cost that would be incurred over the analysis period in accordance to the schedule shown in the previous table.

Refrigerated air dryers

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 40. Summary of Efficient and Baseline Options for Refrigerated Air Dryers

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Non-cycling Refrigerated Air Dryer	Cycling Refrigerated Air Dryer with VFD	**Maintenance**: Frequency is reduced to every 6 years from every 2 years for the baseline non-cycling system.
Equipment Life	15 years	15 years	

NEIs associated with this measure are as follows:

- *Maintenance* – Refrigerator dryers require regular maintenance. For example, refrigerator dryers in factories often draw in dust from the factory, or draw in moisture if vented to the outside. The increased operation time and speed of non-cycling units creates additional heat and draws more dust and dirt that result in additional maintenance needs. A more efficient cycling unit that reduces speed draws in less dust and moisture due to its reduction of full run capacity. Kaeser Compressor[23]

[23] Conversation with service engineer at Kaeser Compressor.

estimates that on a digital scroll and cycling receiver dryer, maintenance frequency is reduced from six years to two.

- *Replacement:* Extending the equipment lifetime is likely but dependent on the environment. Because of this we were unable to justify a lifetime difference.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 41. Cost Schedule for Refrigerated Air Dryers

Year	Baseline	Efficient
1		
2	M	
3		
4	M	
5		
6	M	M
7		
8	M	
9		
10	M	
11		
12	M	M
13		
14	M	
15		

M=Maintenance
R=Repair
P=Replacement

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 42. Cost Breakdown for Refrigerated Air Dryers (Price for Each Occurrence Shown Above)

Baseline	Efficient
Maintain	Maintain
$330	$330

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 43. Lifetime and Annualized Costs for Refrigerated Air Dryers

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 2,231	$ -	$ -	$ 2,231	$ 532	$ -	$ -	$ 532	$ 1,699	$ 117

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Low-pressure drop filters

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 44. Summary of Efficient and Baseline Options for Low-Pressure Drop Filters

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Coalescing filter with initial pressure drop of 1-2 lb. psi and end life of 10 psi	Low-pressure filter with initial pressure drop of < 1 psi over and 3 psi at element changes. Must be deep-bed, mist eliminator style on 15-75 hp. compressors.	None
Equipment Life	5 years	5 years	

This measure does not have any NEIs. The following discussion explains this result.

- *Repair* – Repair costs are equivalent for baseline and efficient options because replacement at end of life is more common than repair within product lifetimes. Many of these filters have ten-year manufacturer guarantees.[24]
- *Maintenance* – Similar to repair, these costs are equal for baseline and efficient technologies. The most common aspect of maintaining filters is replacing the filter cartridge. However, differences between baseline and efficient equipment cartridge change frequencies could not be verified. These costs are dependent on specific factory applications rather than technology type.

Zero loss condensate drains

The following table shows the characteristics of the baseline and efficient options for this measure.

[24] Conversation with Parker Hannifin Corp Compressed Air Filters.

Table 45. Summary of Efficient and Baseline Options for Zero Loss Condensate Drains

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Timed Solenoid Drains	Zero Loss Condensate Drain	**Maintenance**: The advantage of zero loss condensate drains over timed solenoid drains is to avoid needing to replace filters, treat oily condensate, and fix air leaks at an annual cost savings of $12 per drain, with 5 average drains per facility for a total of $60 per year.
Equipment Life	15 years	15 years	

- *Maintenance* – The advantage of zero loss condensate drains over timed solenoid drains is avoiding the need to replace filters and treat oily condensate. In addition, per manufacturer interview, "If a timed solenoid drain valve opens 3 to 4 times per hour, the cost of the wasted air will be $80 per valve, per year."[25] Manufacturer interviews estimated five timed solenoid drains per facility. The actual air leakage is an energy saving measure and not applicable to this study, but the reduction in maintenance due to not having to maintain a baseline system is considered and added. The costs to maintain the baseline system is estimated at $12 per drain, which include the costs to repair the air leaks, replace filters, and treat oily condensate.
- *Repair* – A hypothesis was investigated to determine whether zero loss condensate drains require fewer repairs due to more optimal operation using sensors rather than a simple timer. However, quantification of cost savings is dependent on the application and we were not able to make a specific estimate.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

[25] Parker Balston, 'Coalescing Compressed Air Filters'.

Table 46. Cost Schedule for Zero Loss Condensate Drains

Year	Baseline	Efficient
1	M	-
2	M	-
3	M	-
4	M	-
5	M	-
6	M	-
7	M	-
8	M	-
9	M	-
10	M	-
11	M	-
12	M	-
13	M	-
14	M	-
15	M	-

M=Maintenance

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 47. Cost Breakdown for Zero Loss Condensate Drains (Price for Each Occurrence Shown Above)

Baseline	Efficient
Maintain	Maintain
$60	-

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 48. Lifetime and Annualized Costs for Zero Loss Condensate Drains

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 869	$ -	$ -	$ 869	$ -	$ -	$ -	$ -	$ 869	$ 60

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Electric – compressed air summary

The following tables summarize the NEIs we calculated for the electric compressed air sample categories, as well as the total population of electric compressed air measures installed in 2013.

Table 49. NEI Estimates for Measures in Electric Compressed Air Sample Categories

Measure Type/ Technology	Custom			Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Compressed Air <25 HP Rotary Screw VSD				$ 664	$ 1,527	1
Compressed Air >50 HP Rotary Screw VSD	$ 1,866	$ 3,111	1	$ 3,266	$ 30,050	4
Compressed Air 25- 50 HP Rotary Screw VSD				$ 1,599	$ 7,356	2
Compressor Heat Recovery	$ -	$ -	1			
Cycling Refrigerated Air Dryer with VFD				$ 117	$ 270	1
Zero Loss Condensate	$ 1,599	$ 2,665	1	$ 60	$ 276	2
Low Pressure Drop Filters	$ -	$ -	0	$ -	$ -	0
Overall	**$ 1,155**	**$ 5,776**	**3**	**$ 1,717**	**$ 39,480**	**10**

Table 50. Overall NEI Estimates for Electric Compressed Air Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	3	10
Average NEI per Sample Measure	$ 1,155	$ 1,717
Sample Total NEIs (b)	$ 3,466	$ 17,165
Sample Total kWh Savings (c)	134,314	456,016
NEI/kWH (d = b / c)	$ 0.026	$ 0.038
90% CI Low	$ 0.002	$ 0.033
90% CI High	$ 0.050	$ 0.042
p-value	0.08	0.00
Population Measures (2013) (e)	5	23
Weighted Population Savings kWh (2013) (f = c * (e / a))	223,857	1,048,837
Total Estimated Population NEI (g = d * f)	$ 5,776	$ 39,480

A.2.5 Electric – HVAC

Electric HVAC systems include cooling systems and heat pumps. We also included HVAC controls here. For information on HVAC fan motors and VFDs, see the Motors section of this appendix.

As shown in Table 5, from the population of electric HVAC measures (17 custom and 134 prescriptive) installed in 2013, we drew a sample of 6 custom and 15 prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. In addition, all of the eight electric custom CDA projects we sampled included the installation of at least one electric HVAC measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least nine types of electric HVAC measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following nine types of electric HVAC measures or technologies are considered further in our NEI analysis:

- Air Conditioners & Heat Pumps
- Geothermal Heat Pumps
- High-Efficiency Chillers
- Chilled Beams (Valence Cooling)
- HVAC Controls
- Fans
- Air Handlers
- Humidification
- Low-Pressure Drop (LPD) Filters.

The following sections summarize the NEI estimates for each measure type.

Air conditioners and heat pumps

The following table shows the characteristics of the baseline and efficient options for these measures.

Table 51. Summary of Baseline and Efficient Options for Air Conditioners and Heat Pumps

Sub-Type	Baseline	Efficient	Equipment Lifetime	NEIs (relative to Baseline)
Air conditioner, Air-cooled	ASHRAE 90.1 2007	Exceeds CEE Specifications	15	None
Air Conditioner, Water-cooled				
Heat Pump, Air-cooled				

Small Direct Expansion (DX) systems are the most common electric HVAC system type used in commercial buildings. All air-cooled DX units require similar maintenance;[26] tasks include the following:

- Inspect ducts, filters, blower, and indoor coil for dirt and other obstructions
- Diagnose and seal duct leakage
- Verify adequate airflow by measurement
- Verify correct refrigerant charge by measurement
- Check for refrigerant leaks

[26] http://energy.gov/energysaver/articles/operating-and-maintaining-your-heat-pump.

- Inspect electric terminals, and, if necessary, clean and tighten connections, and apply nonconductive coating
- Lubricate motors, and inspect belts for tightness and wear
- Verify correct electric control, making sure that heating is locked out when the thermostat calls for cooling and vice versa
- Verify correct thermostat operation.

In general, a heat pump or other direct expansion equipment requires the same maintenance no matter the efficiency level. In other words, a 13 EER split systems has the exact same maintenance needs as a 16 EER unit. These maintenance items include preventative maintenance and parts replacement, tube cleaning, open motor shaft seals and bearing, low-pressure purge, and replacement after catastrophic failure. This remains true across almost all air-cooled DX equipment.

Geothermal heat pumps

To calculate NEIs of geothermal systems, the component can be broken into two categories: DX systems and ground loops. The DX component will be as previously described. The ground loops consist of very few parts including pumps, filters, and valves. Although very little can go wrong with these systems, there is some standard maintenance to be performed. According to one source:

> *The indoor components of the geothermal system are electro-mechanical and will suffer from standard wear and tear over a season. Before the summer begins, a technician must look over the indoor cabinet of the heat pump and check that its motors are lubricated, electrical connections tight, coils clean, and the thermostat correctly calibrated. The outdoor components of the system require special maintenance as well. The technician will not need to dig up the coils, but the manifold needs to be checked, and sometimes open loop systems must have an acid flush to remove deposits. Each maintenance visit will involve a thorough test on the loops to make sure they are not leaking and in need of repairs.*[27]

The amount of testing varies based on whether a system is open or closed loop. However, knowing that annual inspection, water testing, filter cleaning, and heat exchanger maintenance are required, it is safe to assume $500 per season to ensure optimal system performance. In addition, the life of the heat exchanger depends on the maintenance. Research showed that they can last as long as 15 years or much less. Included in the costs was $1,199 for a heat exchanger replacement around the half-life of the equipment.

The following table shows the characteristics of the baseline and efficient options for this measure.

[27] http://www.premierindoor.com/blog/geOthermal-service/does-my-geOthermal-heat-pump-need-maintenance-before-each-summer/.

Table 52. Summary of Baseline and Efficient Options for Geothermal Heat Pumps

Sub-Type	Baseline	Efficient	Equipment Lifetime	NEIs (relative to Baseline)
Heat Pump, Ground Source	Air Source Heat Pump with Resistance Heat Backup	Geothermal System that Exceeds CEE Specifications	15	**Maintenance**: Increased maintenance due to geothermal wells.

NEIs associated with this measure are as follows. Note that these do not include maintenance items shared between the baseline and efficient systems:

- *Maintenance* – A geothermal heat pump system requires an annual check of the manifold, periodic flushes with acid water to clear out mineral deposits, and certain additional maintenance items on the heat pump such as maintaining strainers.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 53. Cost Schedule for Geothermal Heat Pumps

Year	Baseline	Efficient
1	-	M
2	-	M
3	-	M
4	-	M
5	-	M
6	-	M
7	-	M
8	-	M
9	-	M
10	-	M
11	-	M
12	-	M
13	-	M
14	-	M
15	-	M

M=Maintenance
R=Repair
P=Replacement

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 54. Cost Breakdown for Geothermal Heat Pumps (Price For Each Occurrence Shown Above)

Baseline	Efficient
Maintain	Maintain
$-	$2479

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 55. Lifetime and Annualized Costs for Geothermal Heat Pumps

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ -	$ -	$ -	$ -	$ 35,908	$ -	$ -	$ 35,908	$ (35,908)	$ (2,479)

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

High efficiency chillers

Chiller Compressors: The main items that draw energy and require maintenance in a chilled water system are the compressors. Oil changes, controls, cleaning, and calibration are just some of the needs. Not maintaining a compressor can be one of the most expensive mistakes building operational staff can make.

The types of compressors considered were scroll, screw, and centrifugal. Within these, a few crucial subcategories were considered. A scroll compressor can utilize a variable speed technology often referred to as “digital scroll,” a screw compressor can utilize a variable speed drive or a slide valve, and a centrifugal can utilize a variable speed drive and incorporate an oil-free magnetic bearing technology. Most, however, require the same maintenance to meet factory recommendations, and to optimize performance and lifespan.

Cooling Tower: It is important to understand cooling tower costs as they result to a water-cooled chiller. If a building baseline system is water-cooled, but an efficient air-cooled chiller is chosen, the cooling tower savings should be calculated.

The following table shows the characteristics of the baseline and efficient options for these measures.

Table 56. Summary of Baseline and Efficient Options for High-Efficiency Chillers

Sub-Type	Baseline[28]	Efficient	Lifetime Years	NEIs (relative to Baseline)
Air-cooled Scroll Chiller	ASHRAE 90.1 2007	Exceeds code and the minimum application requirements.	20	**Maintenance**: Magnetic bearing compressors require less frequent oil changes. Water-cooled chillers require more maintenance. **Repair**: For water-cooled chillers, magnetic bearings require fewer repairs. **Replacement**: Water-cooled chillers last longer.
Air-cooled Screw Chiller	ASHRAE 90.1 2007		20	
Air-cooled Centrifugal Chiller with Magnetic Bearings	ASHRAE 90.1 2007[29]		20	
Water-cooled Screw Chiller	ASHRAE 90.1 2007[30]		20	
Water-cooled Centrifugal Chiller	ASHRAE 90.1 2007[30]		20	
Water-cooled Centrifugal Chiller with Magnetic Bearings	ASHRAE 90.1 2007[30] (WC Centrifugal)		20	

NEIs associated with this measure are as follows:

- *Maintenance* – In general, centrifugal compressors require more maintenance than a screw, and a screw requires more than a scroll compressor. However, a magnetic bearing centrifugal compressor does not require oil and therefore offers a unique and valuable NEI by reducing oil changes, oil analysis, oil pump rebuilding, and oil heater/cooler maintenance. One additional cost unique to a magnetic bearing compressor is a circuit board replacement expected in year 15 due to its advanced controls.[31] Compressors with oil-free technology are becoming more popular.
- Where a major NEI takes effect is if an air-cooled chiller is used instead of a water-cooled chiller with a cooling tower. For example, if a design dictates a new building has a 300-ton load and the building is being evaluated for code compliance using a building simulation model, ASHRAE Appendix G requires the energy use to be analyzed with a water-cooled chiller. However, the actual chiller installed could be an air-cooled chiller with a similar efficiency, or something different if ASHRAE Appendix G and modeling is used for code compliance. Therefore, the baseline will be a water-cooled chiller with a cooling tower, and the proposed will be an air-cooled chiller with no cooling tower. This will affect the NEI, as a cooling tower requires additional needs. This can also happen in reverse, where a water-cooled chiller has an air-cooled chiller as a baseline, thus creating negative NEIs.
- *Repair* – Danfoss[31] includes a compressor repair every five years, for which the cost varies by chiller type.

[28] The same type of compressor (screw, scroll, or centrifugal) was used as the baseline and efficient option unless a different base type was listed by the program documentation or identified by the customer.
[29] For some custom projects, a water-cooled chiller may have been used as baseline.
[30] For some custom projects, an air-cooled chiller may have been used as baseline.
[31] Life Cycle Costing Analysis of Water-cooled Chillers, Danfoss TURBOCOR, Spring 2012.

- *Replacement* – While water-cooled chiller compressors can last much longer, cooling towers and air-cooled compressors, on average, require replacement every 15 years.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 57. Cost Schedule for High-Efficiency Chillers

Year	Air-Cooled			Water-Cooled		
	Scroll	Screw	Centrifugal Magnetic	Screw	Centrifugal	Centrifugal Magnetic
1	M	M	M	M,C	M,C	M,C
2	M	M	M	M,C	M,C	M,C
3	M	M	M	M,C	M,C	M,C
4	M	M	M	M,C	M,C	M,C
5	M,R	M,R	M	M,C,R	M,C,R	M,C
6	M	M	M	M,C	M,C	M,C
7	M	M	M	M,C	M,C	M,C
8	M	M	M	M,C	M,C	M,C
9	M	M	M	M,C	M,C	M,C
10	M,R	M,R	M,R	M,C,R	M,C,R	M,C,R
11	M	M	M	M,C	M,C	M,C
12	M	M	M	M,C	M,C	M,C
13	M	M	M	M,C	M,C	M,C
14	M	M	M	M,C	M,C	M,C
15	M,R	M,R	M	M,T,R	M,T,R	M,T
16				M,C	M,C	M,C
17				M,C	M,C	M,C
18				M,C	M,C	M,C
19				M,C	M,C	M,C
20				M,C	M,C	M,C

M=Chiller Maintenance
R=Compressor Repair
C=Cooling Tower Maintenance
P=Chiller Replacement
T=Cooling Tower Repair

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 58. Cost Breakdown for High-Efficiency Chillers (Price for Each Occurrence Shown Above)[32]

Type	Maintain Chiller[33]	Compressor Repair	Maintain Cooling Tower	Replace Cooling Tower[34]
AC Scroll	$1,032	$2,606	-	-
AC Screw	$1,032	$2,969	-	-
AC Mag. Cent.	$724	$6,154	-	-
WC Screw	$1,032	$1,666	$3,208	$28,208
WC Cent.	$1,032	$2,298		
WC Mag. Cent.	$724	$5,250		

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 59. Lifetime and Annualized Costs for High-Efficiency Chillers

Category	Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
	Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
AC Scroll	Varies	Varies	Varies	Varies	$ 19,716	$ 5,527	$ 6,540	$ 31,783	Varies	Varies
AC Screw					$ 19,716	$ 6,297	$ 17,201	$ 43,214		
AC Mag. Cent.					$ 13,832	$ 6,929	$ -	$ 20,761		
WC Screw					$ 81,005	$ 5,093	$ 18,347	$104,445		
WC Cent.					$ 84,444	$ 7,025	$ 26,630	$118,099		
WC Mag. Cent.					$ 75,121	$ 5,024	$ 10,821	$ 90,966		

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Chilled beam (valence cooling)

A popular new technology uses chilled water to cool the thermal zone of a building rather than supplying cooling through fan-coil units. This technology saves energy, and is also largely maintenance-free. Fan-coil units require belt maintenance, lubrication, and adjustment. Chilled beams do not have moving parts, and therefore do not require the same maintenance. Both technologies require coil cleaning. The sample data did not give a number of chilled beams or comparable fan-coil units. Therefore, DNV GL opted to use the estimate of one unit per 1,000 ft^2 as the baseline.

The following table shows the characteristics of the baseline and efficient options for this measure.

[32] For a custom project, many of the options in this table can be considered as baseline or efficient. Because of the many possible combinations, we omitted the column associated with "NEIs relative to baseline."
[33] http://www.thermalcare.com/central-chillers/tc-series-central-chillers/air-cooled-vs-water-cooled.php.
[34] CBRE/Whitestone CostLab.

Table 60. Summary of Baseline and Efficient Options for Chilled Beams

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Description	Fan Coil Units	Chilled Beam System	**Maintenance**: Less motor bearing greasing, belt changes, and filter changes **Repair**: Reduced repairs due to less mechanical parts
Comparison Units	One Fan Coil Unit per 1000 ft2	One Chilled Beam per 1000 ft2	
Equipment Life	15 years	15 years	

NEIs associated with this measure are as follows:

- *Maintenance* – A fan-coil unit requires motor lubrication once per year, cleaning, belt replacement and adjustment, coil cleaning, filter changes, and drain maintenance.[35] A chilled beam requires regular cleaning just like a fan coil but not the other listed things.[36] Assuming a fan coil can cover 1,000 ft^2, then the reduction in maintenance time compared to a chilled beam can be analyzed.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 61. Cost Schedule for Chilled Beams

Year	Baseline	Efficient
1	M	-
2	M	-
3	M	-
4	M	-
5	M	-
6	M	-
7	M	-
8	M	-
9	M	-
10	M	-
11	M	-
12	M	-
13	M	-
14	M	-
15	M	-

M=Maintenance
R=Repair
P=Replacement

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

[35] http://contractingbusiness.com/service/fan-coil-units-extra-maintenance-steps-worth-extra-effort.
[36] http://contractingbusiness.com/service/chilled-beam-service-requires-whole-building-knowledge.

Table 62. Cost Breakdown for Chilled Beams (Price for Each Occurrence Shown Above)

Baseline Maintain	Efficient Maintain
$60	-

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 63. Lifetime and Annualized Costs for Chilled Beams

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 869	$ -	$ -	$ 869	$ -	$ -	$ -	$ -	$ 869	$ 60

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

HVAC controls

HVAC systems have multitudes of controls; however, only a few were given incentives under our sample. These include dual enthalpy economizers and energy management systems (EMS).

Each of these technologies offer enhanced comfort and safety, which are NEIs, but quantifying those vales was far too dependent on the system type and offered no method of estimating the value. However, calibration of these systems is required.

A baseline for these systems is either an on/off control, or one that floats. These are among the most energy-wasting items in a building. However, focusing on the NEIs, the operational maintenance and retro-commissioning of these controls represent added cost.

EMS systems allow you to more easily implement a retro-commissioning program. The EMS gives you error codes that tell you that maintenance is required. Many EMS operators do certain kinds of maintenance they are told about by their system, but not others. There are as many ways of using an EMS to operate a building as there are EMS operators. There are calibration costs associated with sensors, and additional costs every so often for migrating EMS systems to the newest software versions.

There can also be significant cost savings associated with EMS systems. Depending on the sophistication of the operator, they can find out about equipment operating poorly and correct it, potentially preventing issues that would occur later. These are very difficult to quantify.

Because the costs and benefits of EMS systems are so varied, we decided that we did not have sufficient information to justify any positive or negative NEI cost estimate.

With regard to dual enthalpy economizer controls (DEEC) we determined that the primary difference between baseline and efficient options is the addition of two combination temperature/humidity sensors for each air handling unit. Manufacturers recommend recalibrating these sensors on a regular schedule. Our experience suggests that a majority of customers never calibrate their sensors outside of a periodic retro-commissioning program. The New York City Mayor's Office of Sustainability requires an Energy Efficiency Report (EER) submitted every ten years.[37] Assuming that calibration takes place during this ten-year retro-commissioning cycle, this equals the effective useful life of the equipment and so would not be completed during the life of the DEEC controls.

The following table shows the characteristics of the baseline and efficient options for these measures.

Table 64. Summary of Baseline and Efficient Options for HVAC Controls

Type	Baseline	Efficient	Lifetime Years	NEIs (relative to Baseline)
Dual Enthalpy Economizer Controls (DEEC)	Fixed Dry Bulb Economizer	Dual Enthalpy Economizer	10	None
Energy Management System	None	Energy Management System	15	

Fans

Fans can come in multiple designs, like forward curved, backward curved, radial, and vane axial. None of the information in the selected sample referenced a specific fan style. Also, in general, the fan shape is a method of reducing cost, changing noise, or overcoming pressure. NEIs are not relatable because if a specific style is needed, it inherently becomes the baseline for the design. In some cases a fan type may require more frequent balancing compared to another style. Although this is an NEI, it is probably due to a design constraint like the fan type needing to be explosion proof or to meet a noise constraint. Therefore, fan configuration was not considered valuable as part of this study.

Air handlers

Air handler unit (AHU) incentives are based on a combination of systems within this study. Heat recovery, variable speed drives, economizers, humidification, low-pressure filters, and other systems make up the potential NEIs. The savings and incentives are usually built on prescriptive or energy modeled approaches. The baseline for all AHU systems would be an air handler meeting ASHRAE 90.1 2007 Appendix G guidelines. The proposed system could potentially include a non-air-based design, like a specially designed chilled beam system, radiant heating, or other unique design. However, in the samples chosen, none of these systems were used. Even the samples with chilled beam design used a dedicated outside air unit, meaning a basic AHU was still incorporated. Therefore, we did not find NEIs for AHU systems.

Humidification

Humidification can come in multiple technologies that require specific maintenance. For example, a steam-generated system requires different maintenance than a pressure-driven

[37] http://www.nyc.gov/html/gbee/html/plan/ll87.shtml.

system. However, either way, if humidification is needed, in laboratories for example, there is no standard baseline with which to compare. Because of how specialized the need is for these systems, DNV GL opted to not include the NEIs for this technology. In addition, most incentives for humidification systems are for the boiler or heating element. If a boiler was part of the sample data, the NEIs were considered under the applicable section.

LPD filters

The main benefit of a low-pressure drop (LPD) filter is in the energy saved at the fan motor. It is conceivable that a motor that runs less due to less pressure will run at a lower temperature, thereby run for more hours, and require less maintenance. However, it is more likely in new construction that the motor is sized based on the total pressure required, so an LPD filter equals a smaller horsepower motor requiring similar maintenance to a larger motor. Because of this, DNV GL opted to not include potential NEIs for LPD filters.

Electric – HVAC summary

The following tables summarize the NEIs we calculated for the electric HVAC sample categories, as well as the total population of electric HVAC measures installed in 2013.

Table 65. NEI Estimates for Measures in Electric HVAC Sample Categories

Measure Type/ Technology	Custom			Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Chiller, Air Cooled Scroll (20 yr)				$ -	$ -	3
Custom Chiller	$ 462	$ 5,604	5			
HVAC Controls	$ -	$ -	1	$ -	$ -	2
Unitary HVAC, Air Cooled	$ -	$ -	1	$ -	$ -	10
Overall	**$ 330**	**$ 5,604**	**7**	**$ -**	**$ -**	**15**

Table 66. Overall NEI Estimates for Electric HVAC Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	7	15
Average NEI per Sample Measure	$ 330	$ -
Sample Total NEIs (b)	$ 2,308	$ -
Sample Total kWh Savings (c)	1,581,827	146,235
NEI/kWH (d = b / c)	$ 0.001	$ -
90% CI Low	$ (0.002)	$ -
90% CI High	$ 0.005	$ -
p-value	0.44	0.00
Population Measures (2013) (e)	17	134
Weighted Population Savings kWh (2013) (f = c * (e / a))	3,841,580	1,306,369
Total Estimated Population NEI (g = d * f)	$ 5,604	$ -

A.2.6 Electric – Industrial Process

As shown in Table 5, from the population of electric industrial process measures (five custom and one prescriptive) installed in 2013, we drew a sample of five custom and one prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. None of the eight electric custom CDA projects we sampled included the installation of at least one electric industrial process measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least four types of electric industrial process measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following two types of electric industrial process measures or technologies are considered further in our NEI analysis:

- Injection-molding Machines
- Uninterruptible Power Supplies (UPS)

Several other measure types, such as variable frequency drives and lighting, fell into the industrial process category. NEIs for these measures were developed under other sections of this appendix, and can be found in their appropriate sections.

The following sections summarize the NEI estimates for each measure type.

Injection-molding

Injection-molding machines have been used for many years and commonly come as hydraulic, electric, or hybrid machines. Hydraulic has dominated the market for many years. In recent times, electric injection-molding machines have been replacing hydraulic molding machines. In general, the difference between electric and hydraulic injection-molding machines is that one uses oil to pressurize and inject plastic into a mold, and the other requires no oil. The electric machine avoids oil contamination, leaks, changes, and testing, and heats up and cools down faster. This creates less waste, tighter temperatures, and other factors resulting in increased efficiency and reduced maintenance.

NEIs likely include easier use, less oil maintenance, and less scrap. However, due to process privacy concerns, respondents were only willing to share information about oil-related maintenance. Donaldson Filtration Solutions recommends testing oil every 500 hours, or about monthly on average. In interviewing their engineering staff, we found they have a program that costs $2,500 to perform this service. ACO Mold states, "An all-electric machine can offer unmatched repeatability due to the servo drives that are used for injection forward and clamp rather than hydraulic pumps/valves."[38] This reliability cannot easily be quantified, as it is specific to each business.

[38] http://www.acomold.com/electric-vs-hydraulic-injection-molding-machine.html.

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 67. Summary of Efficient and Baseline Options for Injection Molding

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Hydraulic	Electric	**Maintenance**: Electric model does not require oil servicing.
Flow	Constant Volume	Variable Volume	

NEIs associated with this measure are as follows:

- *Maintenance*: Donaldson Filtration Solutions recommends servicing oil-filled injection-molding machines every 500 hours, or about monthly on average. In interviewing their engineering staff, we found they have a program that costs $2,500 to perform this service. The size and hours of the process of the injection molding machines (IMM) will greatly vary the NEIs. Since the samples were large facilities, DNV GL assumed the IMMs would be maintained along with other machines on a set quarterly schedule.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 68. Cost Schedule for Injection Molding

Year	Baseline	Efficient
1	M	
2	M	
3	M	
4	M	
5	M	
6	M	
7	M	
8	M	
9	M	
10	M	
11	M	
12	M	
13	M	
14	M	
15	M	

M=Maintain

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 69. Cost Breakdown for Injection Molding (Price For Each Occurrence Shown Above)

Baseline Maintain	Efficient Maintain
$5,000	-

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 70. Lifetime and Annualized Costs for Injection Molding

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 72,425	$ -	$ -	$ 72,425	$ -	$ -	$ -	$ -	$ 72,425	$ 5,000

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

UPS

Uninterruptible power supplies are critical systems that will continue to grow in popularity as more and more building equipment is controlled by computers and software. UPS systems act as buffers for power spikes, safe shutdowns, and reliability.

UPS efficiency ratings are found on the nameplate of the equipment and represent how much original incoming utility power is used to power critical load versus how much is lost in the operation of the UPS. For example, according to a fact sheet from Emerson Network Power: “A UPS that is 96% efficient passes 96% of the incoming utility power to the load, while a 94% efficient UPS passes 94% of the input power to the output. However, while a side-by-side comparison indicates that a 96% efficient UPS would yield greater energy savings, it is often overlooked that these ‘nameplate’ ratings only represent full load.”[39]

At part load, a machine that has a less efficient rating can become more efficient than its counterpart. In other words, the efficiency savings is not a straightforward calculation and is very dependent on what the UPS is serving. However, the O&M items that represent the NEIs of UPS systems are the same, as shown below.

[39] http://www.emersonnetworkpower.com/documentation/en-us/brands/liebert/documents/white%20papers/conducting%20an%20accurate%20utility%20cost%20analysis%20based%20on%20ups%20efficiency.pdf.

Table 71. UPS Servicing Requirements[40]

Frequency	Task
Quarterly:	Visually inspect equipment for loose connections, burned insulation or any other signs of wear.
Semiannually:	Visually check for liquid contamination from batteries and capacitors.
	Clean and vacuum UPS equipment enclosures.
	Check HVAC equipment and performance related to temperature and humidity.
Annually:	Conduct thermal scans on electrical connections to ensure all are tight and not generating heat, which is the first and sometimes only indication of a problem. A non-evasive diagnostic tool helps technicians identify hot spots invisible to the human eye. Technicians should re-torque if thermal scan provides evidence of a loose connection.
	Provide a complete operational test of the system, including a monitored battery-rundown test to determine if any battery strings or cells are near the end of their useful lives.
Biannually:	Test UPS transfer switches, circuit breakers and maintenance bypasses.

Since the maintenance items are the same across different systems, and the nature of a UPS is predicated on its not needing much maintenance compared to other building systems, the NEIs are zero dollars.

Electric – industrial process summary

The following tables summarize the NEIs we calculated for the electric industrial process sample categories, as well as the total population of electric industrial process measures installed in 2013.

Table 72. NEI Estimates for Measures in Electric Industrial Process Sample Categories

Measure Type/ Technology	Custom			Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Custom Industrial Process	$ (16)	$ (49)	3			
Injection Molding Electric	$ 10,000	$ 20,000	2			
Other				$ -	$ -	1
Overall	**$ 3,990**	**$ 19,951**	**5**	**$ -**	**$ -**	**1**

[40] http://www.facilitiesnet.com/powercommunication/article/UPS-Maintenance-Checklist-Facility-Management-Power-Communication-Feature--9401.

Table 73. Overall NEI Estimates for Electric Industrial Process Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	5	1
Average NEI per Sample Measure	$ 3,990	$ -
Sample Total NEIs (b)	$ 19,951	$ -
Sample Total kWh Savings (c)	1,565,025	5,389
NEI/kWH (d = b / c)	$ 0.013	$ -
90% CI Low	$ 0.004	$ -
90% CI High	$ 0.022	$ -
p-value	0.02	0.00
Population Measures (2013) (e)	5	1
Weighted Population Savings kWh (2013) (f = c * (e / a))	1,565,025	5,389
Total Estimated Population NEI (g = d * f)	$ 19,951	$ -

A.2.7 Electric – Lighting

Lighting energy savings benefits are so well known it has created new business segments in the retrofit and new construction industry. Between high-output T8s, T5s, LEDs, and controls, many new construction projects include the most advanced lighting technologies.

As shown in Table 5, from the population of lighting measures (24 custom and 440 prescriptive) installed in 2013, we drew a sample of 15 custom and 49 prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. In addition, all of the eight electric custom CDA projects we sampled included the installation of at least one lighting measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least four types of lighting measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following four types of lighting measures or technologies are considered further in our NEI analysis:

- Light Fixtures
- Refrigerated Case Lighting
- Lighting Controls
- Performance Lighting.

The following sections summarize the NEI estimates for each measure type.

Light fixtures

The reduction of life-cycle costs includes extended life, reduced ballast changes, and better lighting distribution. For example, an LED uses less energy and lasts much longer than a T8, and does not require bulb or ballast replacement.

Baseline is an important consideration for lighting. The most common lighting fixture in a non-industrial setting with a 10 ft. ceiling height (the vast majority of our sample) is a three (3) lamp T8 fixture. Using information from various online sources and DNV GL professional judgment, it was determined that the baseline fixture for schools and office spaces would be the 3-Lamp 32-Watt 4' T8. For high bay applications, we considered the baseline to be a 400-watt metal halide. Setting these baseline assumptions proved critical to the life-cycle costing calculations that were performed to assist with creating cost figures for lighting projects.

The interview phase produced a variety of results. Some Massachusetts customers said the "flickering" of the LEDs hurt performance while others said the LEDs' light distribution increased the work performance of the occupants. Universally, customers commented that the smaller LED wall fixtures (PAR16 bulb) required more maintenance and replacements than other technologies. All respondents commented that T5 and T8 ballasts were replaced about every five years, while the lamps were replaced approximately every three years. The LED fixtures require full fixture replacement but none of our respondents had to do it yet due to the longevity of LEDs.

In Massachusetts, it is important to note that rebates for lighting technologies are not only for the lamps but can also be for the ballasts. If the ballast meets an efficiency threshold, then some of the older, less efficient T8 model lamps can still be rebated.[41] While the measures can be rebated, we believe that there will not be any NEIs associated with these cases. Having the more efficient ballast will likely only lead to energy savings, but not produce any non-energy benefits.

The table below shows the characteristics of the baseline and efficient options for this measure. The baseline is always a T8 lamp, but the efficient option can be a T5 and/or an LED. In applications where we were given area (ft^2) only, we assumed 80 ft^2 as a coverage area for a fixture.

[41] http://www.masssave.com/~/media/Files/Business/Applications-and-Rebate-Forms/Retrofit/Lighting-Controls-Retrofit-Form-Mass-Save.pdf.

Table 74. Summary of Efficient and Baseline Options for Light Fixtures

Characteristic	Baseline - T8/HO T8	Efficient – T5	Efficient – LED	NEIs (relative to Baseline)
Type	Linear Fluorescent T8 Fixture	Linear Fluorescent T5 Fixture	Light Emitting Diode Fixture	**Maintenance**: T5 bulbs are brighter than T8s and can light a 20% larger space using the same fixture footprint. This allows for fewer bulb changes. In most conditions, LED fixtures do not require maintenance. **Replacement**: Because T5 lighting layouts require fewer fixtures, on replacement fewer fixtures must be replaced. LED bulb and fixture replacements are less frequent than fluorescent technologies, resulting in a lower labor cost.
Control	Electronic Ballast	Electronic Ballast	Electronic Driver	
Fixture Quantity[42]	1:1	0.9:1	0.9:1	
Fixture Life[43]	10 years	10 Years	10 Years	
Ballast Life[42]	5 Years	5 Years	-	
Bulb Life[42]	3 Years	3 Years	-	

NEIs associated with this measure are as follows:

- *Maintenance:* The only savings from the T5 verses the T8 is the reduction in number of fixtures. A T5 bulb has a smaller diameter than a T8, which makes it closer to the light source and increases the Co-Efficiency of Utilization (CU). In general, a T5 is found to have 10% to 16% increased CU. The NEI utilizes a 10% increase in lighting, which results in less lamps being used at the site.[44]

  All respondents mentioned that there was reduced cost in waste mercury containment, but only one specified that there were savings of "a couple hundred dollars per retrofit." The rest said they could not quantify the savings amount due to it being handled by a "different person or department." Clearwater Services estimates the cost of recycling a fluorescent tube is between six and ten cents per bulb foot, and a pickup fee of between $35 and $50. The common theme from all interviewees was that LEDs are superior to T5 and T8 lights in lifespan, energy consumption, maintenance, and often performance of the tenants.

- *Replacement*: With regard to NEIs, LED fixtures last significantly longer and only need to be replaced every ten years, whereas the T8 and T5 technologies require bulb replacement every three years, and ballast or fixture replacement every five years. Because of the labor costs associated with ballast replacement and the low cost of fixtures when rebates are included, many installers simply replace fixtures (with new bulbs) at the five-year mark rather than changing ballasts and cleaning. This may change as rebates phase out eventually. However, for this study we assumed that lighting rebates will continue to be offered at their current levels throughout the lifetimes of fixtures sold in 2013.

[42] Fixture quantity is based on customer reaction to fixture type. The brightness of T5 fixtures over the T8 baseline caused a reduction in the number of fixtures or bulbs resulting in maintenance saving due to decreased bulbs to change. This does not apply to high bay fixtures.
[43] DNV GL professional opinion.
[44] http://lightingsolutions.ca/blog/t8-vs-t5-fluorescent/.

The following table provides the maintenance cost schedule associated with the baseline and efficient options.

Table 75. Cost Schedule for Light Fixtures

Year	Baseline	T5	LED
1			
2			
3	B,R	B,R	
4			
5	B,F,R	B,F,R	
6			
7			
8	B,R	B,R	
9			
10	F,R	F,R	F
11			
12			
13			
14			
15			

B= Replace Bulbs
F= Fixture or Ballast Replacement (includes new bulbs)[45]
R= Bulb Recycling

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

[45] We found through this study that fixture and ballast replacements cost about the same amount of money in the majority of space types. For this reason, most lighting maintenance people simply replace fixtures rather than ballasts. In year 10, we assumed all fixtures would be replaced with LEDs.

Table 76. Cost Breakdown for Light Fixture (Per Fixture, Price For Each Occurrence Shown Above)

Fixture Type	Replace Bulbs[46]	Recycle Bulbs[47]	Replace Fixtures[43]	Incentive
Baseline T8 or T8HO[48]	$9.90	$3.17	$89	n/a
Efficient T5	$12.00	$2.88	$113	$-25
LED	n/a	n/a	$139	$-50
Baseline High Bay MH	$50	$0.96	$235	n/a
High Bay T5	$40	$4.80	$225	$-100
High Bay LED	n/a	n/a	$305	$-150

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 77. Lifetime and Annualized Costs for Light Fixtures

Category	Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
	Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
Efficient T5	$ -	$ 41	$ 168	$ 209	$ -	$ 46	$ 167	$ 213	$ (4)	$ (0.28)
Efficient LED	$ -	$ 41	$ 168	$ 209	$ -	$ -	$ 81	$ 81	$ 128	$ 8.86
High Bay T5	$ -	$ 150	$ 407	$ 557	$ -	$ 136	$ 300	$ 436	$ 121	$ 8.38
High Bay LED	$ -	$ 150	$ 407	$ 557	$ -	$ -	$ 177	$ 177	$ 380	$ 26.25

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.
"Repair" costs reflect the bulb replacement and bulb recycling costs. "Replace" costs reflect the fixture replacement costs.

Refrigerated case lighting

Refrigerated case lighting receives the same NEI consideration as standard light fixtures. For a discussion on NEIs associated with the contribution of heat to refrigerated cases, see the Section A.2.10 - Refrigeration.

Lighting controls

Investigating NEIs of lighting controls consisted of searching manufacturer recommendations, talking with engineers internally, and performing interviews. According to a paper by Southern California Edison,[49] the benefits of lighting controls systems are energy savings, improved

[46] CBRE/Whitestone CostLab.
[47] Interview results.
[48] Note that these costs are increased by 10% due to the reduction in efficacy from T8 fixtures. For example, T5 fixtures are 10% more expensive, but due to the reduced light output, T8s cost just as much after installation as T5s for a given space.
[49] https://www.sce.com/wps/wcm/connect/1c694bef-e9cc-47a5-87af-698f8c8e9972/Lightning+Controls5_WCAG.pdf?MOD=AJPERES.

productivity by giving employees control of lighting levels, and reduced maintenance by extending lifespan of the lamps.

In our interviews, some said that LEDs had increased flickering, while others said it was reduced. Regarding maintenance, some respondents said that lighting controls systems required constant “tweaking,” which greatly increased service time. Others claimed less fixture maintenance time due to shorter fixture runtimes. Since the NEIs could not be confirmed, denied, or quantified, we did not make an estimate at this time.

Performance lighting

Performance lighting receives the same NEI consideration as standard light fixtures.

In most cases, the program documentation contained information on the approximate numbers of fixtures of each type installed, allowing us to make estimates in the same way. If this information was missing, we selected installed fixtures based on the watts per square foot claimed, according to the following table.

Table 78. Watts per Sq. Ft. Fixture Choices

Watts / Ft2	Fixture Type
0.85–1.00	High-performance T8
0.70–0.84	T5
0.50–0.69	LED

Electric – lighting summary

The following tables summarize the NEIs we calculated for the electric lighting sample categories, as well as the total population of electric lighting measures installed in 2013.

Table 79. NEI Estimates for Measures in Electric Lighting Sample Categories

	Custom			Prescriptive		
Measure Type/ Technology	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Baseline T8				$ -	$ -	7
Custom Lighting	$ 78	$ 497	4			
Efficienct LED	$ 789	$ 2,525	2	$ 2,600	$ 256,838	11
Efficient T5				$ (26)	$ (3,693)	16
High Bay LED				$ 1,534	$ 41,331	3
Lighting Controls				$ -	$ -	9
Lighting Performance	$ 365	$ 4,670	8	$ 1,425	$ 38,398	3
Mini LED (PAR16)	$ -	$ -	1			
Overall	**$ 320**	**$ 7,692**	**15**	**$ 757**	**$ 332,873**	

Table 80. Overall NEI Estimates for Electric Lighting Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	15	49
Average NEI per Sample Measure	$ 320	$ 757
Sample Total NEIs (b)	$ 4,807	$ 37,070
Sample Total kWh Savings (c)	1,549,173	1,818,758
NEI/kWH (d = b / c)	$ 0.003	$ 0.020
90% CI Low	$ (0.001)	$ 0.013
90% CI High	$ 0.007	$ 0.028
p-value	0.24	0.00
Population Measures (2013) (e)	24	440
Weighted Population Savings kWh (2013) (f = c * (e / a))	2,478,677	16,331,706
Total Estimated Population NEI (g = d * f)	$ 7,692	$ 332,873

A.2.8 Electric – Motors

As shown in Table 5, from the population of motors measures (4 custom and 113 prescriptive) installed in 2013, we drew a sample of 4 custom and 37 prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. In addition, none of the eight electric custom CDA projects we sampled included the installation of at least one motors measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least six types of motors measures or technologies (see below for further discussion of those not included here). Upon further review of the available data and information with which we can characterize and estimate NEIs, the following two types of motors measures or technologies are considered further in our NEI analysis:

- Variable Frequency Drives (VFDs)
- HVAC ECM Motors.

The “motors” category in the tracking data also includes several prescriptive measures installed in other systems, including ECM motors, low-energy doors, and anti-sweat heaters. These are listed under the “other” section of this report, as the majority of these three measures—while they are offered under the prescriptive motors program—were actually installed under the custom “other” program.

The following sections summarize the NEI estimates for each measure type included here.

VFDs

Electric motors have been one of the primary drivers of energy efficiency in commercial buildings. The advent of VFDs changed HVAC, process, conveyors, and many other aspects of buildings’ energy use.

Motors running at one speed with no variability can operate with minimal maintenance. This is often not the case, however, as motors change the speed with which air, water, and products are moved. Every manufacturer, utility customer, contractor, and engineer interviewed insisted that there are maintenance implications for a motor with VFD compared to one without. The non-energy related advantages and disadvantages can be summarized as follows:

Advantages

- Reduction of inrush current due to soft start
- Reduced heat due to running at part load
- Ability to adjust speed, which increases productivity
- Packaged systems come pre-programmed

Disadvantages

- Bearings can wear faster, causing premature failure
- Additional electric components are susceptible to failure
- Electrical flux concentrates at specific points inside motor, causing premature failure.

These advantages are irregular, do not always occur, and point in different directions, making them difficult to generalize about or measure. For example, while inrush current constantly changing causes thrust on the bearings, which leads to failure and major motor case damage; this is process-dependent and may or may not result in failure. Heat savings is similar. Many motors last well over 50 years, so even if the heat added or subtracted 25% of the life, the motor would still last its entire expected lifespan.

Considering some applications can have hundreds of these motors (hotels, hospitals, large multi-family, etc.), failures are expected. Most building maintenance teams keep spare motors on hand in preparation. However, there appears to be no difference in the need to store more than one between the baseline and efficient options. Another potential point of non-energy savings is in the air balancing often required during retro-commissioning. However, contractor and maintenance staff interviews did not turn up any examples of a building planning to, or having used, this technique.

While our sample did not include any manufacturing VFDs, we did find that NEIs may exist in some cases. One customer who manufactures food products explained that they use VFDs to adjust cook time based on the food being processed. If the product needed less cook time, they sped the motors up, and the opposite if it needed more cook time. However, the VFDs themselves require more maintenance compared to using the previous braking/over-speed system.

Because our interview results yielded inconsistent findings, we do not recommend the deeming of NEIs for VFDs at this time.

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 81. Summary of Efficient and Baseline Options for Variable Frequency Drives

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Control	Across the line motor control	Variable Speed	None
Lubrication	Greased Bearing	Greased Bearing	
Equipment Life	15 years	15 years	

There are no NEIs associated with this measure, but the standard action for all motors and controllers are as follows:

- Repair – Larger motors are rewound when burnout occurs. Variable speed controls are either repaired or, more than likely, replaced. Electrically commutated (EC) motors are replaced if they fail due to the low cost and small size.
- Maintenance – All motors require scheduled greasing and removing dust and dirt. All control technologies require scheduled cleaning.

HVAC ECM motors

The most commonly incentivized EC motors were installed on fan coil units, air handlers, and DX units. The baseline option is a permanent split capacitor (PSC) motor. The primary advantage of an EC motor is the variable speed control. Most of these motors are designed to run at a set capacity that is not 100%. An EC motor is more efficient than a PSC motor at the set capacity, when used as a variable speed, or multi-speed. Both technologies are relatively maintenance free. Failure typically results from bearing wear and tear. Both motor types use the same type of bearings, and if they fail, they are usually just replaced with new units. There is nothing measurable to show a non-energy benefit of one over the other.

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 82. Summary of Efficient and Baseline Options for HVAC ECM Motors

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Permanently Shaded Coil Motor	Electrically Commutated Motor	None
Lubrication	Greased Bearing	Greased Bearing	
Equipment Life	15 years	15 years	

Electric – motor summary

The following tables summarize the NEIs we calculated for the electric motor sample categories, as well as the total population of electric motor measures installed in 2013.

Table 83. NEI Estimates for Measures in Electric Motor Sample Categories

Measure Type/ Technology	Custom			Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
HVAC ECM Motors				$ -	$ -	10
Refrigerated Case Motors				$ -	$ -	1
Variable Speed Drives	$ -	$ -	4	$ -	$ -	26
Overall	**$ -**	**$ -**	**4**	**$ -**	**$ -**	**37**

Table 84. Overall NEI Estimates for Electric Motor Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	4	37
Average NEI per Sample Measure	$ -	$ -
Sample Total NEIs (b)	$ -	$ -
Sample Total kWh Savings (c)	612,932	1,653,940
NEI/kWH (d = b / c)	$ -	$ -
90% CI Low	$ -	$ -
90% CI High	$ -	$ -
p-value	0.00	0.00
Population Measures (2013) (e)	4	113
Weighted Population Savings kWh (2013) (f = c * (e / a))	612,932	5,051,222
Total Estimated Population NEI (g = d * f)	$ -	$ -

A.2.9 Electric – Other

The electric "other" measure category includes a variety of measures, but the following make up the majority of energy savings. See the applicable sections for estimates of NEIs for these specific measures, which are combined to estimate NEIs for specific projects.

As shown in Table 5, from the population of electric "other" measures (2 custom and 1 prescriptive) installed in 2013, we drew a sample of 2 custom and 1 prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. In addition, none of the eight electric custom CDA projects we sampled included the installation of at least one electric "other" measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least three types of electric "other" measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, we chose to analyze the electric "other" measures in the categories defined for the other categories. These included uninterruptible power supplies (UPS), HVAC controls, lighting controls, and high-efficiency motors.

Electric – other summary

The following tables summarize the NEIs we calculated for the electric "other" sample categories, as well as the total population of electric "other" measures installed in 2013.

Table 85. NEI Estimates for Measures in Electric Other Sample Categories

Measure Type/ Technology	Custom			Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Custom Motors	$ -	$ -	1			
Other	$ -	$ -	1	$ -		1
Overall	**$ -**	**$ -**	**2**	**$ -**	**$ -**	**1**

Table 86. Overall NEI Estimates for Electric Other Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	2	1
Average NEI per Sample Measure	$ -	$ -
Sample Total NEIs (b)	$ -	$ -
Sample Total kWh Savings (c)	567,487	73,616
NEI/kWH (d = b / c)	$ -	$ -
90% CI Low	$ -	$ -
90% CI High	$ -	$ -
p-value	0.00	0.00
Population Measures (2013) (e)	2	1
Weighted Population Savings kWh (2013) (f = c * (e / a))	567,487	73,616
Total Estimated Population NEI (g = d * f)	$ -	$ -

A.2.10 Electric – Refrigeration

This measure category includes energy efficient upgrades to refrigeration systems used in refrigeration of food products in small and large grocery stores, as well as industrial-scale refrigeration systems.

The custom program includes a refrigeration measure category, while the prescriptive program categorizes refrigeration measures as "motors." The prescriptive refrigeration measures (the first three measures listed below) are included in this section for clarity, and because the majority of these measures—while they are offered under the prescriptive program—were actually installed under the custom program.

As shown in Table 5, from the population of refrigeration measures (13 custom and zero prescriptive) installed in 2013, we drew a sample of 5 custom measures to characterize the types of technologies deployed in NC and their associated NEIs. In addition, none of the eight custom CDA projects we sampled included the installation of at least one refrigeration measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least four types of refrigeration measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following four types of refrigeration measures or technologies are considered further in our NEI analysis:

- ECM Refrigerated Case Motors
- Low-Energy Doors
- Anti-Sweat Heater Controllers
- Industrial Ammonia Refrigeration System.

The following sections summarize the NEI estimates for each measure type.

ECM refrigerated case motors

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 87. Summary of Efficient and Baseline Options for ECM Refrigerated Case Motors

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Motor Type	Permanently Shaded Coil	Electrically Commutated	None
Refrigeration System Configuration	Multiplex Direct Expansion	Multiplex Direct Expansion	
Compressor Type	Reciprocating	Reciprocating	
Refrigerated Cases per Compressor Rack	20	20	
Equipment Life	10 years	10 years	

No NEIs are associated with this measure.

- *Maintenance* – While some manufacturers claim that refrigeration system maintenance costs are reduced due to the use of ECMs, maintenance NEIs could not be verified for this measure. Refrigeration system maintenance is shown to be similar for baseline and proposed cases, including cleaning evaporator coils, drain pans, fans and intake screens, and condenser coils; lubricating motors and hinges; inspecting door gaskets and seals; and checking refrigerant charge as necessary.

Low-energy doors

Low-energy doors reduce the infiltration of heat from outside of a refrigerated space. The following table shows the characteristics of the baseline and efficient options for this measure.

Table 88. Summary of Efficient and Baseline Options for Low-Energy Doors

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Door Type	Standard Door	Low Energy Door	None
Refrigeration System Configuration	Multiplex Direct Expansion	Multiplex Direct Expansion	
Compressor Type	Reciprocating	Reciprocating	
Refrigerated Cases per Compressor Rack	20	20	
Compressor Life	10 years	10 years	

No NEIs are associated with this measure.

Anti-sweat heater controllers

Anti-sweat mechanisms heat the customer-facing glass of refrigerated glass in order to eliminate condensation and increase visibility for contained products. Controls on anti-sweat mechanisms reduce the heat input to the refrigerated case by controlling how often anti-sweat heaters are activated.

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 89. Summary of Efficient and Baseline Options for Anti-Sweat Heater Controllers

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Heater Control	Always On	Timer or Sensor Control	None
Refrigeration System Configuration	Multiplex Direct Expansion	Multiplex Direct Expansion	
Compressor Type	Reciprocating	Reciprocating	
Refrigerated Cases per Compressor Rack	20	20	
Compressor Life	10 years	10 years	

No NEIs are associated with this measure.

Industrial ammonia refrigeration system

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 90. Summary of Efficient and Baseline Options for Industrial Ammonia Refrigeration Systems

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Multiple Split Systems	Single Multi-Compressor Ammonia System	**Maintenance**: External maintenance contracts are more expensive for the more complex ammonia system. **Repairs**: Compressor replacements are reduced from 4 to 2 over a 40-year system life. **Replacement:** Condenser lifetimes are extended from 20 years to at least 50 years.
Equipment Life	Compressor: 10 years Package: 20 years	Compressor: 23 years Condenser: 50 years	

NEIs associated with this measure are as follows:[50]

- *Maintenance* – For large industrial refrigeration systems, maintenance is largely performed by contractors under annual maintenance contracts. These contracts cover routine maintenance and small repairs. The cost for these contracts is more expensive for the more complex ammonia system.
- *Repairs* – The baseline system requires a compressor replacement at 10 years, while the ammonia system requires a condenser replacement at 20 years. These are considered repairs, since the structure of the system remains intact.
- *Replacement* – The baseline system has a condenser lifetime of 20 years, at which time the entire packaged unit is typically replaced. Ammonia systems often last 50 years or more, beyond our analysis period.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

[50] Detailed costs for repairs, replacement, and maintenance contract came from an interview with Christopher Murphy from American Other Company.

Table 91. Cost Schedule for Industrial Ammonia Refrigeration Systems[51]

Year	Baseline	Efficient
1	M	M
2	M	M
3	M	M
4	M	M
5	M	M
6	M	M
7	M	M
8	M	M
9	M	M
10	M,R	M
11	M	M
12	M	M
13	M	M
14	M	M
15	M	M
16	M	M
17	M	M
18	M	M
19	M	M
20	M,P	N,R
21	M	M
22	M	M
23	M	M

M=Maintenance R=Compressor Repair
P=Replacement N=Condenser Repair

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 92. Cost Breakdown for Industrial Ammonia Refrigeration Systems (Price for Each Occurrence Shown Above)

Baseline			Efficient		
Maintenance	Compressor Repair	Replacement	Maintenance	Condenser Repair	Compressor Repair
15,000	120,000	300,000	30,000	110,000	200,000

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

[51] Detailed costs for repairs, replacement, and maintenance contract came from an interview with Christopher Murphy from American Other Company.

Table 93. Lifetime and Annualized Costs for Ammonia Refrigeration Systems

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 654,867	$ 22,779	$ -	$ 677,646	$327,433	$114,846	$ 57,154	$499,433	$ 178,213	$ 8,164

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Electric – refrigeration summary

The following tables summarize the NEIs we calculated for the electric refrigeration sample categories, as well as the total population of electric refrigeration measures installed in 2013.

Table 94. NEI Estimates for Measures in Electric Refrigeration Sample Categories

Measure Type/ Technology	Custom Average Annual NEI	Custom Total Weighted Annual NEI	Custom Sampled Measures
Custom Other	$ 8,164	$ 21,227	1
Custom Refrigeration	$ 10,123	$ 26,320	1
Refrigerated Case Motors	$ -	$ -	3
Overall	**$ 3,657**	**$ 47,547**	**5**

Table 95. Overall NEI Estimates for Electric Refrigeration Sample Categories

	Custom
Sampled Measures (a)	5
Average NEI per Sample Measure	$ 3,657
Sample Total NEIs (b)	$ 18,287
Sample Total kWh Savings (c)	1,506,974
NEI/kWH (d = b / c)	$ 0.012
90% CI Low	$ 0.003
90% CI High	$ 0.021
p-value	0.03
Population Measures (2013) (e)	13
Weighted Population Savings kWh (2013) (f = c * (e / a))	3,918,132
Total Estimated Population NEI (g = d * f)	$ 47,547

A.2.11 Electric – Overall

The following table shows the overall population NEI estimates for custom and prescriptive electric.[52]

Table 96. Overall Electric NEI Results

Measure Type/ Technology	Custom Electric		Prescriptive Electric	
	Total Annual NEI	Sampled Measures	Total Annual NEI	Sampled Measures
Electric Building Shell	$ -	1		
Electric Commercial Kitchen			$ -	1
Electric Comprehensive Design	$ 2,691.48	8	$ -	0
Electric Compressed Air	$ 5,776.19	3	$ 39,479.77	10
Electric HVAC/ Heat Recovery	$ 5,604.31	7	$ -	15
Electric Industrial Process	$ 19,950.89	5	$ -	1
Electric Lighting	$ 7,691.67	15	$ 332,873.42	49
Electric Motors	$ -	4	$ -	37
Electric Other	$ -	2	$ -	1
Electric Refrigeration	$ 47,546.81	5		
Electric Overall	**$ 89,261.37**	**50**	**$ 372,353.19**	**114**

A.2.12 Gas – Comprehensive Design

The Mass Save® program defines Comprehensive Design as follows:

> *For new commercial construction buildings over 100,000 square feet the Comprehensive Design Approach (CDA) is available. CDA is a Custom approach designed to maximize electric and gas energy savings and financial incentives for the project. It is a whole-building systems approach with interaction of mechanical and electrical systems, including the building envelope design, for building optimization in energy-saving performance.*[53]

CDA requires a specific analysis of multiple systems integrated into a design. The analysis usually involves an energy model of some kind. The NEIs relating to CDA combine multiple technologies. Analyzing the non-energy impact involves combining many technologies across the utility incentive program.

[52] The estimates shown in Table 96 are intended to illustrate the estimated magnitude of the total annual NEIs realized for true NC projects in 2013 because they include NEIs for some measure categories that did not meet the test for statistical significance.
[53] http://www.masssave.com.

The Gas - Comprehensive Design measure category includes a wide variety of measures, but the following make up the majority of energy savings. See the applicable sections for estimates of NEIs for these specific measures, which are combined to estimate NEIs for specific projects.

Gas HVAC

- Boilers
- HVAC Controls
- Infrared Heaters
- Hot Water Heaters.

Building Shell

- Insulation & Air Sealing
- Windows.

Table 97 provides a detailed breakdown of NEIs for each measure rolled up within each CDA project. The "Total Annual NEI" column provides a weighted estimate of annual NEIs for each measure. There were a number of Gas CDA projects that contained electric measures. NEIs were not calculated for these measures. Table 98 provides an overall summary of the CDA sample category.

Table 97. NEIs by Gas CDA Project

CDA Project	Measure Type/ Technology	Custom Average Annual NEI	Custom Total Weighted Annual NEI	Custom Measures in CDA Project
27	Boilers	$ (89)	$ (112)	1
27	Building Shell	$ -	$ -	1
27	HVAC	$ -	$ -	3
27	Lighting	$ -	$ -	2
27	Motors	$ -	$ -	1
27	Other Gas Heating	$ -	$ -	1
27	**Overall**	**$ (10)**	**$ (112)**	**9**
30	**Overall**	**$ -**	**$ -**	**1**
31	Boilers	$ (149)	$ (186)	1
31	Building Shell	$ -	$ -	2
31	HVAC	$ -	$ -	3
31	Lighting	$ -	$ -	2
31	Motors	$ -	$ -	1
31	**Overall**	**$ (17)**	**$ (186)**	**9**
32	Boilers	$ (122)	$ (153)	1
32	Building Shell	$ -	$ -	1
32	HVAC	$ -	$ -	1
32	Motors	$ -	$ -	1
32	Refrigeration	$ -	$ -	1
32	**Overall**	**$ (24)**	**$ (153)**	**5**
35	Building Shell	$ -	$ -	1
35	HVAC	$ -	$ -	5
35	Lighting	$ -	$ -	3
35	Other Gas Heating	$ -	$ -	1
35	**Overall**	**$ -**	**$ -**	**10**
49	Boilers	$ (292)	$ (365)	1
49	Building Shell	$ -	$ -	1
49	HVAC	$ -	$ -	3
49	Other Gas Heating	$ (97)	$ (122)	1
49	**Overall**	**$ (65)**	**$ (486)**	**6**
52	Boilers	$ (184)	$ (230)	1
52	Building Shell	$ -	$ -	1
52	HVAC	$ -	$ -	2
52	Lighting	$ -	$ -	2
52	Other Gas Heating	$ -	$ -	1
52	**Overall**	**$ (26)**	**$ (230)**	**7**
54	HVAC	$ -	$ -	8
54	Lighting	$ -	$ -	2
54	**Overall**	**$ -**	**$ -**	**10**
Overall Weighted Gas CDA		**$ (117)**	**$ (1,167)**	**8**

Table 98. Summary of NEIs for Gas CDA Projects

	Custom
Sampled Measures (a)	8
Average NEI per Sample Measure	$ (117)
Sample Total NEIs (b)	$ (934)
Sample Total Therms Savings (c)	246,418
NEI/kWH (d = b / c)	$ (0.004)
90% CI Low	$ (0.008)
90% CI High	$ 0.000
p-value	0.13
Population Measures (2013) (e)	10
Weighted Population Savings Therms (2013) (f = c * (e / a))	308,023
Total Estimated Population NEI (g = d * f)	$ (1,167)

A.2.13 Gas – Boilers

As shown in Table 5, from the population of boilers measures (10 custom and 68 prescriptive) installed in 2013, we drew a sample of 5 custom and 34prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. In addition, five of the eight gas custom CDA projects we sampled included the installation of at least one boiler measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least two types of boiler measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following type of boiler measures or technologies are considered further in our NEI analysis:

- Condensing boilers.

Condensing boilers

Boilers are the most energy-intensive end use in many Massachusetts facilities. The primary fuel for boilers is natural gas, with energy transferred to steam or hot water for distribution.

There are a variety of configurations for these units, often with designs unique to a manufacturer. The major typical components are the burner, heat exchanger tubes, water treatment unit, flue, and controls.

Modern high-efficiency units take the traditional designs and incorporate a condensing heat exchanger that captures additional energy by extracting latent heat from combustion exhaust.

High-efficiency boilers account for the largest energy savings of any single prescriptive measure in the prescriptive gas tracking data for each of the last five years (2010–2014). DNV GL has performed three separate evaluations on this measure. The current prescriptive gas program utilizes tiers of boiler sizes based on capacity and efficiency. The same size and efficiency designations were utilized for calculating NEIs to produce a common format.

The calculations and estimates shown here are based primarily on CostLab projected maintenance and repair costs, DNV GL internal expertise, and expert interviews. The following table shows the characteristics of the baseline and efficient options for this measure.

Table 99. Summary of Efficient and Baseline Options for Boilers

Characteristic		Baseline	Efficient	NEIs (relative to Baseline)
Type		Massachusetts Building Code Compliant Gas-fired Boiler (ASHRAE 90.1, 2007)	Condensing Hot Water Boiler	**Maintenance**: Efficient technologies require higher maintenance costs, which vary by unit size.
Efficiency	< 300 MBH	82% AFUE	>90% AFUE	
	>300 to 2,500 MBH	80% Thermal Efficiency	> 90% Thermal Efficiency	
	>2,500 MBH	82% Combustion Efficiency	> 90% Thermal Efficiency	
Exclusive Maintenance Requirements		N/A	Condensate Trap Secondary Heat Exchanger	
Equipment Life		25 years	25 years	

NEIs associated with this measure are as follows:

- *Maintenance* – All boilers require annual maintenance, and larger systems are often monitored daily to ensure optimum operating efficiency. The boiler controls must be calibrated to carefully restrict the combustion process within an allowable air variance, and the water levels must be regulated to prevent overheating. Basic cleaning and rust removal allows for gauges and monitoring instruments to be operating and readable. The vent connections and flue must be cleared of obstructions. Monitoring the boiler water blowdown process for steam boilers eliminates the build-up of concentration of dissolved solids in the water. The entrance into boiler piping of air or raw water, per the undetected leakage of water, may lead to pitting, corrosion, and formation of sludge, sediment, or scale.

- High-efficiency boilers require additional maintenance for the condensing heat exchanger. The use of a secondary heat transfer process causes the formation of condensate on the tubing coils, which means that the boiler water must be chemically treated more judiciously than in a traditional system. Residue will build up over time, and can clog condensate traps and drain systems, as well as congest the boiler's combustion chamber. These residues must be cleaned out and managed. Subject matter experts indicated that modern systems typically have advanced control systems and automated sensor alarms to speed the process. In addition, the acidic water must be treated from a condensing boiler in some cases prior to flushing.

- *Repair* – All boilers need repairs during their useful life, requiring labor and materials. Control boards may fail, leaks will form around seals, and heat exchangers may corrode. Air infiltration and scale build-up often are the cause of repairs. Larger systems require lifts or cranes for extensive repairs. High-efficiency units have been found to require additional repair/replacement concerns.

- *Replacement* – Considerable uncertainty exists in the area of lifetime assumptions for new high-efficiency boilers as compared to conventional, standard-efficiency non-condensing units. Due to the condensate, materials are typically specified as corrosion resistant. However, the cabinet and appurtenances often are not. None of our interview respondents was willing to provide an estimate of the shortened lifespan, therefore no calculation adjustment has been made to account for the difference in replacement.
- A review of warranties for condensing units found that condensing boilers typically have a shorter coverage period. This suggests that condensing boilers have up to a 40% shorter lifespan than a non-condensing unit. However, product offerings of high-efficiency technology are only entering the second decade of lifetime, so trustworthy field data is still being accumulated. As the technology matures, a more accurate NEI estimate should be established, which would incorporate the likely early replacement cost of this measure.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 100. Cost Schedule for Boilers

Year	Baseline	Efficient
1	M	M
2	M	M
3	M	M
4	M	M
5	M,R	M,R
6	M	M
7	M	M
8	M	M
9	M	M
10	M,R	M,R
11	M	M
12	M	M
13	M	M
14	M	M
15	M,R	M,R
16	M	M
17	M	M
18	M	M
19	M	M
20	M,R	M,R
21	M	M
22	M	M
23	M	M
24	M	M

M=Maintenance
R=Repair

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 101. Cost Breakdown for Boilers (Price for Each Occurrence Shown Above)

Size Category	Baseline		Efficient	
	Maintain	Repair	Maintain	Repair
<300 MBH	$510	$2,378	$510	$2,760
301 to 499 MBH	$811	$2,738	$1,042	$2,869
500 to 999 MBH	$1,044	$3,473	$1,231	$3,709
1000 to 1699 MBH	$1,639	$4,078	$1,639	$4,685
1700 to 2000 MBH	$3,277	$5,474	$3,277	$5,661

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 102. Lifetime and Annualized Costs for Boilers

Category	Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
	Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
<300 MBH	$ 12,040	$ 9,008	$ -	$ 21,048	$ 12,040	$ 10,455	$ -	$ 22,495	$ (1,447)	$ (61)
301 to 499 MBH	$ 19,155	$ 10,369	$ -	$ 29,524	$ 24,628	$ 10,868	$ -	$ 35,496	$ (5,972)	$ (253)
500 to 999 MBH	$ 24,656	$ 13,156	$ -	$ 37,812	$ 29,089	$ 14,049	$ -	$ 43,138	$ (5,326)	$ (225)
1000 to 1699 MBH	$ 38,721	$ 15,447	$ -	$ 54,168	$ 38,721	$ 17,744	$ -	$ 56,465	$ (2,297)	$ (97)
1700 to 2000 MBH	$ 77,415	$ 20,735	$ -	$ 98,150	$ 77,415	$ 21,439	$ -	$ 98,854	$ (704)	$ (30)

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Gas – Boiler Summary

The following tables summarize the NEIs we calculated for the gas-boiler sample categories, as well as the total population of gas boiler measures installed in 2013.

Table 103. NEI Estimates for Measures in Gas Boiler Sample Categories

Measure Type/ Technology	Custom			Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Boiler	$ (179)	$ (358)	1			
Boiler Condensing - <300MBH All				$ (61)	$ (490)	4
Boiler Condensing - 1000 - 1700 MBH	$ (97)	$ (194)	1	$ (97)	$ (2,333)	12
Boiler Condensing - 1700 - 2000 MBH	$ (30)	$ (179)	3	$ (30)	$ (298)	5
Boiler Condensing - 301 to 499 MBH				$ (253)	$ (2,022)	4
Boiler Condensing - 500 to 999 MBH				$ (225)	$ (3,607)	8
Efficient - Condensing, Standalone, Gas, 75kBTU/h < X < 155kBTU/h				$ (266)	$ (532)	1
Overall	**$ (73)**	**$ (731)**	**5**	**$ (137)**	**$ (9,283)**	**34**

Table 104. Overall NEI Estimates for Gas Boiler Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	5	34
Average NEI per Sample Measure	$ (73)	$ (137)
Sample Total NEIs (b)	$ (365)	$ (4,641)
Sample Total Therms Savings (c)	63,925	55,267
NEI/kWH (d = b / c)	$ (0.006)	$ (0.084)
90% CI Low	$ (0.013)	$ (0.111)
90% CI High	$ 0.001	$ (0.057)
p-value	0.19	0.00
Population Measures (2013) (e)	10	68
Weighted Population Savings Therms (2013) (f = c * (e / a)	127,850	110,534
Total Estimated Population NEI (g = d * f)	$ (731)	$ (9,283)

A.2.14 Gas – Building Shell

As shown in Table 5, from the population of gas building-shell measures (1 custom and zero prescriptive) installed in 2013, we drew a sample of 1 custom measure to characterize the types of technologies deployed in NC and their associated NEIs. In addition, six of the eight gas custom CDA projects we sampled included the installation of at least one gas building shell measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least two types of gas building shell measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following two types of gas building shell measures or technologies are considered further in our NEI analysis:

- Insulation & Air Sealing
- High-performance Windows.

Please see Section A.2.2 (Electric – Building Shell) for a discussion of NEI estimates for this measure category. The NEI estimates were calculated in the same way for both electric and gas building shell measures, since the equipment underlying our calculation of NEIs is not fuel-specific for this measure category.

Gas – building shell summary

The following tables summarize the NEIs we calculated for the gas building shell sample categories, as well as the total population of gas building shell measures installed in 2013.

Table 105. NEI Estimates for Measures in Gas Building Shell Sample Categories

Measure Type/ Technology	Custom		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Building Shell	$ -	$ -	1
Overall	**$ -**	**$ -**	**1**

Table 106. Overall NEI Estimates for Gas Building Shell Sample Categories

	Custom
Sampled Measures (a)	1
Average NEI per Sample Measure	$ -
Sample Total NEIs (b)	$ -
Sample Total Therms Savings (c)	57
NEI/kWH (d = b / c)	$ -
90% CI Low	$ -
90% CI High	$ -
p-value	0.00
Population Measures (2013) (e)	1
Weighted Population Savings Therms (2013) (f = c * (e / a))	57
Total Estimated Population NEI (g = d * f)	$ -

A.2.15 Gas – Commercial Kitchen

Commercial kitchen equipment NEIs are based on the equipment taking less time to maintain and clean (fewer labor hours), requiring less cleaning product, or requiring less cooking medium (water or oil).As shown in Table 5, from the population of commercial kitchen measures with gas savings (zero custom and 14 prescriptive) installed in 2013, we drew a sample of 9 prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. None of the eight gas custom CDA projects we sampled included the installation of any commercial kitchen measures.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least three types of commercial kitchen measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following three types of commercial kitchen measures or technologies are considered further in our NEI analysis:

- Commercial Ovens
- Commercial Steam Cookers
- Commercial Fryers.

The following sections summarize the NEI estimates for each measure type.

Commercial ovens

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 107. Summary of Efficient and Baseline Options for Commercial Ovens[54]

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Annual operation hours[55]	Convection Oven: 3,130 Combination Oven: 3,756	Convection Oven: 3,130 Combination Oven: 3,756	**Maintenance**: Efficient combination ovens reduce water use by 43,800 gallons per year, saving associated water and wastewater costs
Equipment Life	12 years	12 years	

No repair, maintenance, or replacement NEIs were determined to result from replacements of commercial convection ovens.

NEIs associated with this measure are as follows:

- *Water use* – Convection ovens were not found to have reductions in maintenance costs. Efficient combination ovens reduced water use over the baseline technology, with an associated reduction in costs.[56] Consistent to the TRM, all water is assumed to end its life as wastewater (rather than evaporated), such that wastewater costs decrease with water savings.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

[54] No conveyor ovens were sampled as part of this analysis.
[55] Based on TRM assumption of 6 day/week operation, or 313 days/year. Convection ovens are assumed to operate 10 hours/ day, and combination ovens are assumed to operate 12 hours/day.
[56] http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php.

Table 108. Cost Schedule for Commercial Ovens

Year	Combination		Convection	
	Baseline	Efficient	Baseline	Efficient
1	W			
2	W			
3	W			
4	W			
5	W			
6	W			
7	W			
8	W			
9	W			
10	W			
11	W			
12	W			

W=Water Use

The table below shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 109. Cost Breakdown for Commercial Ovens (Price for Each Occurrence Shown Above)

Size Category	Baseline Water Use	Efficient Water Use
Full Size Combination Oven	$108	-
Full Size Convection Oven	-	-

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 110. Lifetime and Annualized Costs for Commercial Ovens

Category	Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
	Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
Combination	$ 1,265	$ -	$ -	$ 1,265	$ -	$ -	$ -	$ -	$ 1,265	$ 108
Convection	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Commercial steam cookers

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 111. Summary of Efficient and Baseline Options for Commercial Steam Cookers

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Steam Generator	Boilerless	**Maintenance**: Efficient commercial steamers reduce water use. Each efficient steamer requires more filter replacements and less de-liming maintenance.
Percentage of Time in Constant Steam Mode	40%	40%	
Average Water Consumption Rate (gal./hr.)	40	3	
Idle Energy Electric (kW)	1.2	0.4	
Equipment Life	12 years	12 years	

NEIs associated with this measure are as follows:

- *Maintenance* – Efficient commercial steamers reduce water use over the baseline technology, with an associated reduction in costs.[57] Consistent with the TRM, all water is assumed to end its life as wastewater (rather than evaporated), such that wastewater costs decrease with water savings. Each efficient steamer contains two water filters not included in baseline equipment; these filters are replaced once quarterly for a total of eight filter replacements per year. Efficient steamers require de-liming maintenance once quarterly rather than the once-monthly service required by baseline equipment, resulting in a decrease in both chemical cost and internal staff maintenance time. All of these maintenance requirement changes were corroborated by customer interviews.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

[57] http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php.

Table 112. Cost Schedule for Commercial Steam Cookers

Year	Baseline	Efficient
1	M	M
2	M	M
3	M	M
4	M	M
5	M	M
6	M	M
7	M	M
8	M	M
9	M	M
10	M	M
11	M	M
12	M	M

M=Maintenance

The table below shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 113. Cost Breakdown for Commercial Steam Cookers (Price for Each Occurrence Shown Above)

Size Category	Baseline Maintenance	Efficient Maintenance
All	$966	$3788

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 114. Lifetime and Annualized Costs for Commercial Steam Cookers

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 11,266	$ -	$ -	$ 11,266	$ 44,185	$ -	$ -	$ 44,185	$ (32,919)	$ (2,822)

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Commercial fryers

The following table shows the characteristics of the baseline and efficient options for this measure.

Table 115. Summary of Efficient and Baseline Options for Commercial Fryers

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Shortening Capacity	65	65	**Maintenance**: Baseline requires increased fryer oil replacement, filter pads, filter powder, oil filtering, and annual contractor maintenance time.
Equipment Life	12 years	12 years	

NEIs associated with this measure are as follows:

- *Maintenance* – Baseline technology requires higher maintenance costs relative to efficient equipment, including increased fryer oil replacement, filter pads, filter powder, internal maintenance time for oil filtering, and annual contractor maintenance time. Filters are not needed for the efficient equipment, and an estimated 30 minute (minimum) oil filtering operation is reduced from once every two days to once every two months, per customer interviews. The largest proportion of maintenance savings results from average annualized savings of fryer oil replacement due to the self-cleaning operation of the efficient unit. Because burned particles do not contaminate the oil, fryer oil life is greatly increased. Finally, external contractor maintenance time is reduced from once annually to once every three years.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 116. Cost Schedule for Commercial Fryers

Year	Baseline	Efficient
1	M	M
2	M	M
3	M	M
4	M	M
5	M	M
6	M	M
7	M	M
8	M	M
9	M	M
10	M	M
11	M	M
12	M	M

M=Maintenance

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 117. Cost Breakdown for Commercial Fryers (Price for Each Occurrence Shown Above)

Size Category	Baseline Maintenance	Efficient Maintenance
All	$6,983	$130

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 118. Lifetime and Annualized Costs for Commercial Fryers

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 81,444	$ -	$ -	$ 81,444	$ 1,513	$ -	$ -	$ 1,513	$ 79,931	$ 6,853

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Gas – commercial kitchen summary

The following tables summarize the NEIs we calculated for the gas commercial kitchen sample categories, as well as the total population of gas commercial kitchen measures installed in 2013.

Table 119. NEI Estimates for Measures in Gas Commercial Kitchen Sample Categories

Measure Type/ Technology	Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Commercial Oven	$ -	$ -	4
Efficient Fryer	$ 6,853	$ 42,641	4
Efficient Steamer	$ (2,822)	$ (4,390)	1
Commercial Steam Cooker	$ -	$ -	0
Overall	**$ 2,732**	**$ 38,250**	**9**

Table 120. Overall NEI Estimates for Gas Commercial Kitchen Sample Categories

	Prescriptive
Sampled Measures (a)	9
Average NEI per Sample Measure	$ 2,732
Sample Total NEIs (b)	$ 24,589
Sample Total Therms Savings (c)	7,235
NEI/kWH (d = b / c)	$ 3.399
90% CI Low	$ 0.961
90% CI High	$ 5.836
p-value	0.02
Population Measures (2013) (e)	14
Weighted Population Savings Therms (2013) (f = c * (e / a))	11,254
Total Estimated Population NEI (g = d * f)	$ 38,250

A.2.16 Gas – HVAC/Heat Recovery

As shown in Table 5, from the population of HVAC / heat recovery measures (12 custom and 27 prescriptive) installed in 2013, we drew a sample of 7 custom and 13 prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. In addition, seven of the eight custom CDA projects we sampled included the installation of at least one HVAC / heat recovery measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least three types of HVAC / heat recovery measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following three types of HVAC / heat recovery measures or technologies are considered further in our NEI analysis:

- Hot Water Heating
- Heat Recovery
- HVAC Controls.

The HVAC controls measure type is discussed in Section A.2.5, Electric – HVAC. Because NEIs for this measure type are not based upon fuel type, the NEIs for this measure are the same between electric and gas.

Below we summarize the NEI estimates for water heaters and heat recovery.

Water heaters

Hot water is often a necessity in commercial applications for cleaning, personnel hygiene, and food preparation purposes. Conventional water heaters transfer energy from a gas burner to a storage tank or heat exchanger filled with water. Insulated inner and outer shells add insulation and physical protection.

In a tank-style system, a small gas burner heats the tank to the temperature defined by a control system or thermostat, and a pressure relief valve keeps the pressure within safe limits. A sacrificial anode, typically magnesium or aluminum with a steel core, prevents corrosion.

Installation of a high-efficiency water heater is often recommended as a target for energy reduction. There are a number of incentivized options available:

- ENERGY STAR®-certified commercial water heaters include gas storage units that use 25% less energy than a conventional commercial unit by employing more efficient heat exchangers.
- Condensing water heaters add a draft-inducing fan to force combustion exhaust through a secondary heat exchanger. In addition, the acidic water must be treated from a condensing boiler prior to flushing.
- Indirect water heaters use a storage tank that is heated by excess heat from an adjacent main boiler. The water tank both eliminates the need for a burner, and balances the boiler temperature variance, saving energy and potentially extending its useful life by limiting the need to cycle as often.
- Tankless water heaters circulate water through a heat exchanger to be heated for immediate use, eliminating the standby heat loss associated with a storage tank.

The sizing of the water heater depends on the flow rate and temperature rise needed for its application, which could be supplying a whole building or a remote space (e.g., bathrooms). Secondary NEIs could be potentially assigned depending on the end-use application, as condensing water heaters are able to heat water much faster. Tankless heaters have no standby losses and are not powered on under low-flow conditions, but typically have a low thermal efficiency. Tankless heaters also are limited to certain minimum and maximum flow rates. An indirect water heater is essentially just a tank with coils, with the performance tied to that of the supply boiler. They can also force the supply boiler to run in months it would typically be shut down.

The calculations and estimates shown here are based primarily on CostLab projected maintenance and repair costs, DNV GL internal expertise, and expert interviews. The measure calculations were dependent on baseline heating as defined by the Massachusetts TRM 2013. The following table shows the characteristics of the baseline and efficient options for this measure.

Table 121. Summary of Baseline and Efficient Options for Water Heaters

Charac-teristic	Baseline	Efficient	NEIs (relative to Baseline)	Analysis Period
Type	Per Code Hot Water Heater <75 MBH EF = 0.59	ENERGY STAR Certified Freestanding <75 MBH EF > 0.67	**Maintenance**: Requires periodic vent clearing service. **Repairs**: Requires a system flush once during lifetime.	13 years
		Indirect Water Heater CAE > 85%	**Maintenance**: Requires heat exchanger flushes.	15 years
		Tankless (electronic ignition) 50 to 200 MBH EF > 0.82	**Maintenance**: Additional labor for heat exchange elements to be descaled with a vinegar flush (often vinegar based) and filters cleaned.	20 years
	Per Code Hot Water Heater 75 to 300 MBH E_{th} = 80%	Condensing Stand-alone Water Heater 75 to 300 MBH E_{th} > 95%	**Maintenance**: Water must be chemically treated before release to reduce acidity	13 Years

NEIs associated with this measure are as follows:

- *Maintenance* – All hot water heaters require periodic maintenance for safety and performance.
  - Baseline: Tank systems require a cleaning and a flush-out after seven years in order to avoid a reduction in equipment lifetime. The vent connections and flue must be cleared of obstructions every three years. There are few electrical components, while parts and service providers are common. Models with larger heating elements have a much better resistance to mineral build-up.
  - ENERGY STAR® Freestanding: Similar to baseline.
  - Indirect: Indirect heaters require heat exchanger flushes every three years.
  - Condensing Freestanding: The use of a secondary heat transfer process encourages the formation of corrosive condensate on the tubing coils. The water must be chemically treated before release for being too acidic.
  - Tankless: Dependent on the hardness of the water, heat exchange elements must be descaled with a flush (often vinegar based) and filters must be cleaned. There is typically more maintenance than the baseline, but fewer repairs and a longer lifespan.
- *Repair* – All hot water heaters require parts replacement during their useful life, requiring labor and materials. Control boards may fail, leaks will form around seals, and heat exchangers may corrode. Air infiltration and scale build-up often are the cause of repairs. Larger systems require lifts or cranes for extensive repairs.
  - Baseline: Tank systems may have the heating element or the gas control valve fail well before the system must be replaced. Temperature controls may fail; the pressure relief valve may become jammed. A sacrificial anode replacement will extend the tank lifespan. Tank failure is the only reason to replace a unit.

  - ENERGY STAR Freestanding: Similar to conventional units.
  - Indirect: The likely components to fail are the temperature control and circulator pump, or leaks due to corrosion. Replacement depends on the associated boiler lifespan.
  - Condensing Freestanding: The use of a secondary heat transfer process precipitates the formation of condensate on the tubing coils. Colder water in the coils increases the potential for condensate formation. The water must be chemically treated before release for being too acidic.
  - Tankless: Most tankless water heaters have a life expectancy of more than 20 years, and easily replaceable parts.

- *Replacement*: High-efficiency condensing units have been found to require additional repair/replacement concerns. However, considerable uncertainty exists in the area of lifetime assumptions for condensing units resulting from the acidic condensate. Because of this uncertainty, we did not consider lifetime differences resulting from condensing heat exchangers.

The measure calculations were dependent on baseline heating as defined by the Massachusetts TRM 2013. This measure category compared size-comparable hot water heater measures. The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 122. Cost Schedule for Water Heaters

Year	Baseline	Indirect	Tankless	ENERGY STAR Freestanding	Condensing Freestanding (75–300 MBH)
1			M		
2			M		
3	M	M	M	M	M
4			M		
5			M		R
6	M	M	M	M	M
7	R		M	R	
8			M		
9	M	M	M	M	M
10			M, R		R
11			M		
12	M	M	M	M	M
13	P		M	P	P
14			M		
15		M	M		
16	M		M	M	M
17			M		
18		M	M		
19	M		M	M	M

M=Maintenance R=Repair P=Replacement

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 123. Cost Breakdown for Water Heaters (Price for Each Occurrence Shown Above)

<table>
<tr><th rowspan="2">Measure</th><th colspan="3">Baseline</th><th colspan="3">Efficient</th></tr>
<tr><th>Maintain</th><th>Repair</th><th>Replace</th><th>Maintain</th><th>Repair</th><th>Replace *</th></tr>
<tr><td>ENERGY STAR Freestanding</td><td rowspan="6">$38</td><td rowspan="6">$500</td><td rowspan="3">$2,796</td><td rowspan="4">$38</td><td>$465</td><td rowspan="6">-</td></tr>
<tr><td>Indirect</td><td>-</td></tr>
<tr><td>Tankless (75–155 MBH)</td><td rowspan="2">$620</td></tr>
<tr><td>Tankless (155–200 MBH)</td><td>$6,360</td></tr>
<tr><td>Condensing Freestanding (75–155 MBH)</td><td>$2,796</td><td rowspan="2">$310</td><td rowspan="2">$240</td></tr>
<tr><td>Condensing Freestanding (155–300 MBH)</td><td>$11,710</td></tr>
</table>

* In no case is the efficient version of the equipment replaced during the analysis period, so the cost of replacement is not applicable.

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 124. Lifetime and Annualized Costs for Water Heaters

Category	Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
	Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
ENERGY STAR Freestanding	$ 148	$ 485	$ -	$ 633	$ 125	$ 450	$ -	$ 575	$ 58	$ 5
Indirect	$ 148	$ 955	$ 626	$ 1,729	$ 155	$ -	$ -	$ 155	$ 1,574	$ 109
Tankless (75–155 MBH)	$ 220	$ 955	$ 1,650	$ 2,825	$ 732	$ 598	$ -	$ 1,330	$ 1,495	$ 78
Tankless (155–200 MBH)	$ 220	$ 955	$ 1,650	$ 2,825	$ 732	$ 598	$ -	$ 1,330	$ 1,495	$ 78
Condensing Freestanding (75–155 MBH)	$ 148	$ 955	$ -	$ 1,103	$ 4,491	$ 464	$ -	$ 4,955	$ (3,852)	$ (266)
Condensing Freestanding (155–300 MBH)	$ 148	$ 955	$ -	$ 1,103	$ 4,491	$ 464	$ -	$ 4,955	$ (3,852)	$ (266)

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

** In no case is the efficient version of the equipment replaced during the analysis period, so the cost of replacement is not applicable.

Heat recovery

When comparing an air handler with heat recovery verses a baseline with no heat recovery, it is possible additional maintenance will be required. However, a heat pipe requires little maintenance, a plate heat wheel requires motor maintenance, and a heat recovery wheel with a silica gel descant requires motor maintenance and occasional cleaning.

DNV GL opted to exclude the potential additional maintenance time necessary for a heat wheel because the addition of the heat wheel means a reduction of the size of the AHU, thereby slightly reducing the maintenance of the total unit; and, due to the reduction on the coils and motors, heat recovery may extend the lifespan of the equipment. Further study of each specific building would be needed to know if a heat wheel is adding to or reducing the NEIs of the specific sample.

Gas – HVAC/heat recovery summary

The following tables summarize the NEIs we calculated for the Gas HVAC/heat recovery sample categories, as well as the total population of gas HVAC/heat recovery measures installed in 2013.

Table 125. NEI Estimates for Measures in Gas HVAC/Heat Recovery Sample Categories

Measure Type/ Technology	Custom			Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Compressor Heat Recovery	$ -	$ -	1			
Custom Chiller	$ 10	$ 49	3			
Efficient - Condensing, Standalone, Gas, 75kBTU/h < X < 155kBTU/h				$ (266)	$ (1,105)	2
Efficient - Indirect Water Heater				$ 109	$ 1,354	6
HVAC Controls	$ -	$ -	3			
Tankless (electronic ignition) >200k BTU/h				$ 78	$ 813	5
Overall	**$ 4**	**$ 49**	**7**	**$ 39**	**$ 1,062**	**13**

Table 126. Overall NEI Estimates for Gas HVAC/Heat Recovery Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	7	13
Average NEI per Sample Measure	$ 4	$ 39
Sample Total NEIs (b)	$ 29	$ 511
Sample Total Therms Savings (c)	125,352	2,115
NEI/kWH (d = b / c)	$ 0.000	$ 0.242
90% CI Low	$ (0.000)	$ (0.174)
90% CI High	$ 0.001	$ 0.657
p-value	0.41	0.34
Population Measures (2013) (e)	12	27
Weighted Population Savings Therms (2013) (f = c * (e / a))	214,889	4,393
Total Estimated Population NEI (g = d * f)	$ 49	$ 1,062

A.2.17 Gas – Other

As shown in Table 5, from the population of gas “other” measures (7 custom and zero prescriptive) installed in 2013, we drew a sample of 5 custom measures to characterize the types of technologies deployed in NC and their associated NEIs. None of the eight custom CDA projects we sampled included the installation of at least one gas “other” measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least three types of gas “other” measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following three types of gas “other” measures or technologies are considered further in our NEI analysis:

- Boilers
- Furnaces
- Water Heaters.

Despite being categorized as gas “other,” these measures actually fit well under other categories and are analyzed under their own sections. Please see the appropriate sections for NEI estimates for each of these measures.

Gas – other summary

The following tables summarize the NEIs we calculated for the gas “other” sample categories, as well as the total population of gas “other” measures installed in 2013.

Table 127. NEI Estimates for Measures in Gas Other Sample Categories

	Custom		
Measure Type/ Technology	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Custom Other	$ (277)	$ (1,938)	5
Overall	**$ (277)**	**$ (1,938)**	**5**

Table 128. Overall NEI Estimates for Gas Other Sample Categories

	Custom
Sampled Measures (a)	5
Average NEI per Sample Measure	$ (277)
Sample Total NEIs (b)	$ (1,385)
Sample Total Therms Savings (c)	43,860
NEI/kWH (d = b / c)	$ (0.032)
90% CI Low	$ (0.092)
90% CI High	$ 0.029
p-value	0.39
Population Measures (2013) (e)	7
Weighted Population Savings Therms (2013) (f = c * (e / a))	61,404
Total Estimated Population NEI (g = d * f)	$ (1,938)

A.2.18 Gas – Industrial Process

As shown in Table 5, from the population of gas industrial process measures, 2 custom and zero prescriptive were installed in 2013. We drew a sample of 2 custom measure to characterize the types of technologies deployed in NC and their associated NEIs. None of the eight custom CDA projects we sampled included the installation of at least one gas industrial process measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least one type of gas industrial process measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following type of gas industrial process measure or technology is considered further in our NEI analysis:

- Infrared Heating.

For the analysis of NEIs associated with infrared heating, see Section A.2.19, other gas heating.

Gas – Industrial process summary

The following tables summarize the NEIs we calculated for the gas industrial process sample categories, as well as the total population of gas industrial process measures installed in 2013.

Table 129. NEI Estimates for Measures in Gas Industrial Process Sample Categories

	Custom		
Measure Type/ Technology	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Custom Industrial Process	$ 72	$ 144	2
Overall	**$ 72**	**$ 144**	**2**

Table 130. Overall NEI Estimates for Gas Industrial Process Sample Categories

	Custom
Sampled Measures (a)	2
Average NEI per Sample Measure	$ 72
Sample Total NEIs (b)	$ 144
Sample Total Therms Savings (c)	20,608
NEI/kWH (d = b / c)	$ 0.007
90% CI Low	$ (0.011)
90% CI High	$ 0.025
p-value	0.51
Population Measures (2013) (e)	2
Weighted Population Savings Therms (2013) (f = c * (e / a))	20,608
Total Estimated Population NEI (g = d * f)	$ 144

A.2.19 Gas – Other Gas Heating

As shown in Table 5, from the population of other gas heating measures (2 custom and 7 prescriptive) installed in 2013, we drew a sample of two custom and five prescriptive measures to characterize the types of technologies deployed in NC and their associated NEIs. In addition, none of the eight custom CDA projects we sampled included the installation of at least one other gas heating measure.

Based on our review of the PA tracking data for these sampled measures, the information obtained in our interviews, and the supporting documentation provided by the PAs for the projects we sampled, we identified at least two types of other gas heating measures or technologies. Upon further review of the available data and information with which we can characterize and estimate NEIs, the following two types of other gas heating measures or technologies are considered further in our NEI analysis:

- Furnaces
- Infrared Heaters.

The following sections summarize the NEI estimates for each measure type.

Furnaces

Furnaces heat air and distribute the heated air through the building using ducts. Older furnace systems had efficiencies in the range of 56% to 70%, and most manufacturers still produce non-condensing models with only one heat exchanger. These units have a minimum code-mandated efficiency of 80%, and are sometimes referred to as mid-efficiency units. These units use metal pipe for the hot combustion exhaust.

Modern heating systems utilize a condensing system with a secondary heat exchanger to bring the efficiency up to over 90%. With the addition of a variable speed blower motor, furnaces achieve efficiencies as high as 98.5%. Two-stage furnaces are also used to reduce the fuel burned and limit the firing rate. The most expensive and efficient units use a modulating multi-stage firing configuration.

A condensing furnace utilizes the water vapor produced in the combustion process and transfers the heat from this condensation. High efficiency furnaces are better at converting fuel into direct heat and better insulated to reduce heat loss. The higher efficiencies are achieved by sending flue gasses through a secondary heat exchanger that extracts heat from the exhaust gasses.

If the building is constructed to be exceptionally air tight, an additional heat recovery ventilator (HRV) or energy recovery ventilator (ERV) is added to provide fresh air (with an ERV also adding humidity). Often these units are dedicated outdoor air units and require small furnaces to heat the air to 55°F-65°F to avoid distributing sub-freezing air into the space.

The calculations and estimates shown here are based primarily on CostLab projected maintenance and repair costs, DNV GL internal expertise, and expert interviews. The following table shows the characteristics of the baseline and efficient options for this measure.

Table 131. Summary of Efficient and Baseline Options for Furnaces

<table>
<tr><th>Characteristic</th><th>Baseline</th><th>Efficient</th><th>NEIs (relative to Baseline)</th></tr>
<tr><td>Type</td><td>Massachusetts State Building Code Compliant Furnace</td><td>High-efficiency Furnace w/ electronically commutated motor (ECM)</td><td rowspan="3">Maintenance: A condensing furnace requires minimal extra labor.
Repair: Higher efficiency units incorporate corrosive condensates, reducing durability.</td></tr>
<tr><td>Efficiency</td><td>90% AFUE</td><td>AFUE > 95%</td></tr>
<tr><td>Equipment Life</td><td>18 years</td><td>18 years</td></tr>
</table>

NEIs associated with this measure are as follows:

- *Maintenance* – All furnaces have a common process of using cold air from a return, drawing it through a filtering system, heating the air using a gas burner with electronic ignition and heat exchanger, and expelling the hot air to the distribution system using circulation fans. Air filters must be replaced in equal frequency monthly or quarterly. Annual maintenance typically only involves inspection, motor oiling, belt checks, and dust/soot cleanout of the grill, heat exchanger, and duct fan. A condensing furnace requires minimal extra attention, as it has two heat exchangers, one for primary heat exchange and a secondary heat exchanger to handle the corrosive condensed exhaust gases. There is also carbonic acid condensate resulting from the gases going through the secondary heat exchanger, which must be drained, and requires a clean-out of a PVC discharge pipe.
- *Repair* – Furnace systems are generally low maintenance. The main sources of repair are burners, distribution fans, controls, and thermostat. Mechanical failures, clogged filters, and thermostat malfunctions all require minimal replacement parts to bring the furnace back to working order. Estimates for repair between baseline and efficient units, however, remain comparable.
- *Replacement* – Although presently estimated to have similar lifespans, higher efficiency technology units must contend with corrosive condensates. While this may shorten the lifespan of the equipment, we did not find sufficient evidence to justify an NEI claim.

Infrared heaters

Task heating equipment is becoming popular in areas with difficult environmental control situations. These include warehouses, hangars, garages, and loading docks where—due to door opening—it is difficult to maintain a comfortable condition. Gas-fired, low intensity infrared heating systems are a more efficient measure than unit heaters, furnaces, or other types of air heating equipment. Low-intensity infrared heaters provide on-demand heat; the burner control box ignites a gas/air mixture and hot gases are pushed through steel radiant tubing by an internal fan. As these gases pass through the assembly, the tubing is heated and emits infrared energy, which is then directed toward the floor by highly polished reflectors. This energy is absorbed by objects in its path, such as the floor, machinery, and people. Objects in the path of the infrared energy in turn re-radiate this heat to create a comfort zone at the floor level.

The true advantage of infrared heaters is the direct comfort factor encountered with the use of radiant heat rather than the inefficiency of conventional heaters working to heat large quantities of air surrounding a person or object within a large conditioned space. Proper equipment selection and layout of the IR heaters are critical to ensure proper heating.

The calculations and estimates shown here are based primarily on CostLab projected maintenance and repair costs, DNV GL internal expertise, and expert interviews. The following table shows the characteristics of the baseline and efficient options for this measure.

Table 132. Summary of Efficient and Baseline Options for Infrared Heaters

Characteristic	Baseline	Efficient	NEIs (relative to Baseline)
Type	Gas-fired Unit Heater (80%)	Gas-Fired Low-Intensity Infrared Heating Unit	**Maintenance**: The fan and motor for a unit heater is larger, and requires additional maintenance. The reflector shield on the IR heater may require polishing. The tube of the IR heater also serves as the exhaust, therefore a cleaning of the long run is necessary. **Repair**: The larger fan on the unit heater is more costly to replace.
Equipment Life	17 Years	17 Years	

NEIs associated with this measure are as follows:

- *Maintenance* – Some of the components are similar, and should only require maintenance periodically on the burner assembly, controls, and exhaust. The fan and motor for a unit heater is larger, and requires additional attention. The reflector shield on the IR heater may require polishing. The tube of the IR heater also serves as the exhaust; therefore a cleaning of the long run is necessary over time.
- *Repair* – Neither the unit heater nor the IR heater is susceptible to breakdowns, and both have lengthy lifespans. The larger fan on the unit heater is more costly to replace.

The following table shows the schedule of costs associated with the baseline and efficient options for this measure.

Table 133. Cost Schedule for Infrared Heaters

Year	Baseline	Efficient
1	M	M
2	M	M
3	M	M
4	M	M
5	M	M
6	M	M
7	M	M
8	M,R	M,R
9	M	M
10	M	M
11	M	M
12	M	M
13	M	M
14	M	M
15	M	M
16	M,R	M,R
17	M	M

M=Maintenance
R=Repair
P=Replacement

The following table shows the prices associate with each cost listed above. Each value in the table represents a single letter above.

Table 134. Cost Breakdown for Infrared Heaters (Price for Each Occurrence Shown Above)

Baseline		Efficient	
Maintain	Repair	Maintain	Repair
$3,290	$620	$2,820	$380

The following table shows these costs totaled across the analysis period on an NPV basis, as well as the cost differences (NEIs) between baseline and efficient, both on an NPV and annualized basis.

Table 135. Lifetime and Annualized Costs for Infrared Heaters

Baseline Costs* (Analysis Period—$2015)				Efficient Option Costs* (Analysis Period—$2015)				Efficient Option NEIs (relative to baseline)	
Maintain	Repair	Replace	Total	Maintain	Repair	Replace	Total	Total NPV	Amortized per year
$ 2,500	$ 1,185	$ -	$ 3,685	$ 2,500	$ 714	$ -	$ 3,214	$ 471	$ 29

* Reflects the total NPV cost that would be incurred in accordance to the schedule shown in the previous two tables.

Gas – other gas heating summary

The following tables summarize the NEIs we calculated for the other gas heating sample categories, as well as the total population of other gas heating measures installed in 2013.

Table 136. NEI Estimates for Measures in Gas Other Gas Heating Sample Categories

Measure Type/ Technology	Custom			Prescriptive		
	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures	Average Annual NEI	Total Weighted Annual NEI	Sampled Measures
Gas Heating - Other				$ -	$ -	2
Infrared Heater Low-Intensity IR Heater				$ 29	$ 121	3
Other	$ -	$ -	2			
Overall	**$ -**	**$ -**	**2**	**$ 17**	**$ 121**	**5**

Table 137. Overall NEI Estimates for Gas Other Gas Heating Sample Categories

	Custom	Prescriptive
Sampled Measures (a)	2	5
Average NEI per Sample Measure	$ -	$ 17
Sample Total NEIs (b)	$ -	$ 86
Sample Total Therms Savings (c)	46,466	1,634
NEI/kWH (d = b / c)	$ -	$ 0.053
90% CI Low	$ -	$ 0.043
90% CI High	$ -	$ 0.063
p-value	0.00	0.00
Population Measures (2013) (e)	2	7
Weighted Population Savings Therms (2013) (f = c * (e / a))	46,466	2,288
Total Estimated Population NEI (g = d * f)	$ -	$ 121

A.2.20 Gas – Overall

The following table shows the overall population NEI estimates for custom and prescriptive gas.[58]

Table 138. Overall Gas NEI Results

	Custom Gas		Prescriptive Gas	
Measure Type/ Technology	Total Annual NEI	Sampled Measures	Total Annual NEI	Sampled Measures
Gas Boilers	$ (730.84)	5	$ (9,282.62)	34
Gas Building Shell	$ -	1	$ -	0
Gas Commercial Kitchen			$ 38,250.28	9
Gas Comprehensive Design	$ (1,166.93)	8	$ -	0
Gas HVAC/ Heat Recovery	$ 49.40	7	$ 1,061.91	13
Gas Industrial Process	$ 144.08	2		
Gas Other	$ (1,938.45)	5		
Gas Other Gas Heating	$ -	2	$ 121.03	5
Gas Overall	**$ (3,642.75)**	**30**	**$ 30,150.60**	**61**

[58] The estimates shown in Table 138 are intended to illustrate the estimated magnitude of the total annual NEIs realized for true NC projects in 2013 because they include NEIs for some measure categories that did not meet the test for statistical significance.

APPENDIX B: BACKGROUND AND PRELIMINARY RESEARCH

This appendix describes the preliminary and Stage 1 research conducted by the Evaluation Team. This research determined the direction for the Stage 2 research, which is described in Section 2.3.

Estimating NEIs requires information concerning changes to the participant's costs (e.g., operations and maintenance, waste management, or administration costs), production output, or revenues resulting from the installed measure.

In the 2012 C&I NEI Retrofit study, the baseline conditions for natural replacement measures were determined by identifying the costs and revenues prior to the replacement of the non-energy efficient equipment. Interviewed respondents were able to use their experience prior to the installation of the incentivized measure as a frame of reference for cost or revenue changes to assess the NEIs. However, only cost and revenue changes associated with equipment being energy efficient (not being new) were relevant. Thus, the NEI value should reflect the incremental difference in costs or benefits of the new energy-efficient equipment relative to new standard-efficiency equipment; this can be difficult for participants to conceptualize and self-report for a number of reasons.

First, in the case of a new facility, there was not a pre-existing structure that participants could use as a reference point to compare cost and revenue changes. While some of the existing literature suggested using experience at a different facility as a point of comparison, there may be many dissimilarities between operations at the new facility and other facilities for which respondents do not account. In the case of a major retrofit, it is not appropriate to compare current operations to the previous facility because the renovated facilities are often so drastically altered that the pre-renovated facility does not offer a valid point of comparison. For natural replacement measures, participants may have similar difficulty identifying an appropriate comparison point that only accounts for the NEIs associated with the equipment being energy efficient (not simply "new").

Therefore, for all types of NC projects—natural replacement, major renovation, and new construction—a key challenge for deriving NEI estimates is the ability of end-users to conceptualize changes relative to the counterfactual baseline if asked in an interview. Determining how best to overcome this challenge was the primary focus of the Stage 1 research.

As a preliminary research activity, the Evaluation Team conducted a literature review to determine if existing NEI research could provide a suitable approach to estimate baseline conditions to isolate NEIs. The studies reviewed by the Evaluation Team are listed below. These studies employed a range of survey techniques that included direct query, conjoint analysis, market actor interviews, and on-site visits. They also used a range of techniques to establish the baseline conditions, which included comparing the installed technology to building codes, standard efficiency measures, or the respondent's previous experience in other facilities with standard efficiency measures.

NYSERDA 2004[59]

- Approach – Used the direct query method (asked program participants, contractors, architects, and engineers to assign a value to each NEI in terms of percentage of the project's estimated energy savings), and collected data to estimate NEIs through in-person interviews, focus groups, mail and telephone surveys, field observations, and site visits
- NEI categories – Maintenance costs, equipment performance, tenant satisfaction, tenant comfort, building aesthetics/appearance, noise levels, lighting/quality of light, building safety, environmental effects, equipment lifetime, ability of tenants to stay in their units
- Baseline for NEIs – On-site interviews with building owners. For the Small Commercial Lighting Program (SCLP), the study also used the ASHRAE 90.1 1989 standard and minimum efficiency levels required by the National Appliance Energy Conservation Act (NAECA)

Barkett et al. 2006[60]

- Approach – Combination of (1) the direct query method of C&I program participants and non-participants and (2) a conjoint analysis approach, which gave respondents hypothetical situations of products from which to choose
- NEI categories – Lighting quality, thermal comfort and HVAC effectiveness, occupant productivity, noise levels, doing good for the environment, O&M costs, indoor air quality, ease of selling/leasing
- Baseline for NEIs – Asked the respondent to compare their old and new buildings and/or similar buildings in the area just meeting levels required by the State Energy Code

Bemont and Skumatz 2007[61]

- Approach – Interviews with a random sample of developers, owners, architects, engineers, vendors, participants, and non-participants. Asked participants whether they were aware of NEIs that were read from a list of pre-defined NEI choices
- NEI categories – Equipment performance, productivity, tenant satisfaction, comfort, appearance, quality of light, building safety, noise, equipment lifetime, sick days

[59] New York Energy Smart Program Evaluation and Status Report. 2004. *New York Energy Smart Program Evaluation and Status Report, Volume 2.* Report to the Systems Benefit Charge Advisory Group.
[60] Brent Barkett, Nicole Wobus, Rachel Freeman, Daniel Violette, Scott Dimetrosky. 2006. *Non-Energy Impacts (NEI) Evaluation.* Prepared for the New York State Energy Research and Development Authority. Prepared by Smith Blue Consulting & Quantec, LLC.
[61] Dawn Bemont & Lisa Skumatz. 2007. *New Non-Energy Benefits (NEBs) results in the commercial / industrial sectors: Findings from incentive, retrofit, and technical assistance /new construction programs.* ECEEE 2007 Summer Study, *Skumatz Economic Research Association.*

- Baselines for NEIs – Standard efficiency equipment

Bicknell and Skumatz 2004[62]

- Approach – Computer-assisted telephone interviewing (CATI) surveys and in-depth interviews with owners, developers, architects, and engineers. The owners/occupants and facility managers were asked about NEI valuations based on their experience, whereas specifiers/decision-makers were asked about their perceptions of the NEIs and perceptions of the value to owners
- NEI categories – Maintenance costs, equipment performance, tenant satisfaction, tenant comfort, building aesthetics/appearance, noise levels, lighting/quality of light, building safety, environmental effects/benefits, equipment lifetime, ability of tenants to stay in unit
- Baseline for NEIs – Not specifically stated

Mills et al. 2005[63]

- Approach – Compared NEIs on new construction commissioning to existing building commissioning, and reviewed Lawrence Berkeley National Laboratory (LBNL) publications and project files
- NEI categories – Reduced change orders, safety impacts, O&M costs
- Baseline for NEIs – Review of literature

Our review of these studies provided limited methodological guidance in developing baseline conditions for the present study beyond those used in the 2012 C&I NEI Retrofit study. While each study used various techniques to address baseline conditions, the Evaluation Team did not find that any of them convincingly overcame the challenge of establishing baseline conditions.

Our concerns with the reviewed studies include the following:

- The research pointed to the need to contrast the installed measures to standard efficiency equipment; however, a number of studies used ASHRAE or local building codes to establish baseline conditions, not standard equipment.
- The studies did not necessarily capture the full range of cost and revenue changes that may result from the efficient measures.

[62] Charles Bicknell & Lisa Skumatz. 2004. *Non-Energy Benefits (NEBs) in the Commercial Sector: Results from Hundreds of Buildings.* ACEEE Proceedings 2004, Skumatz Economic Research Association.

[63] Evan Mills, Norman Bourassa, Mary Ann Piette, Hannah Friedman, Tudi Haasl, Tehesia Powell, and David Claridge. 2005. *The Cost-Effectiveness of Commissioning New and Existing Commercial Buildings.* National Conference on Building Commissioning: May 4-6, 2005. Prepared by the Lawrence Berkeley National Laboratory, Portland Energy Conservation Inc., and Texas A&M University.

- Barkett et al. (2006) separated projects into types based on whether or not the new construction replaced a similar building at a different location. It did not distinguish NC measures at a more refined level. The Evaluation Team believed measures should be further separated into the following categories based on distinctions made by the PAs in administering their NC programs: new building, major retrofit, and natural replacement.

We concluded that none of the previous studies offered a single approach that would be appropriate for estimating NEIs associated with the variety of measures covered by the Massachusetts NC program. As such, we proceeded with the Stage 1 research to identify one or more approaches for estimating NEIs associated with the 2013 NC program. The Stage 1 research included two key components to assess the most appropriate means of estimating NEIs for NC measures:

- *Data mining* – DNV GL analyzed the 2013 program tracking data and the 2012 C&I NEI Retrofit study results to support the remaining tasks in the Stage 1 research.
- *In-depth interviews* – We used information from the data mining task to identify a sample of interviewees from four groups: 1) PA staff who market the NC programs; 2) Design firms (engineers and architects); 3) Manufacturers and suppliers of energy efficient technologies; and 4) Energy managers and operations groups of large institutional participants (e.g., large customers with multiple facilities such as college campuses, government offices, or manufacturing facilities). We then completed 54 interviews to determine the appropriate means of establishing baseline conditions for new construction measures.

The result of this effort was a detailed work plan for Stage 2.

APPENDIX C: COMPARISON OF NC NEI RESULTS TO 2012 C&I RETROFIT NEI RESULTS

As part of our analysis, we compared the current results to the results calculated as part of the 2012 C&I Retrofit study. In some cases, results for the same technology types were vastly different. Comparing the sources of NEIs from both studies, these differences are explained by the following:

- The mix of measures within each measure category was different during the 2012 C&I Retrofit NEI study compared to the NC NEI study.
- Respondents to our survey during the 2012 C&I Retrofit study focused on O&M cost differences over the period of time they had owned the equipment (1–2 years), versus expected lifetime O&M differences between baseline and efficient technologies, as considered in the NC engineering analysis.
- The NC engineering analysis could not account for some NEIs captured by the C&I Retrofit study survey, such as increased sales, productivity, and rent revenue related to installing efficient measures.

Table 139 provides a qualitative comparison of some of the measures studied as part of the NC and Retrofit studies.

Table 139. New Construction versus Retrofit NEIs

Technology	Retrofit NEI Sources	New Construction NEI Sources	Retrofit vs. New Construction NEI Comparison
Boilers	•Boiler requires 120 fewer internal maintenance hours each year. •Customer reduced external HVAC contractor visits. •Customer saved dozens of hours in avoided administrative costs processing and paying for maintenance work. •Property value increased several hundred thousand dollars due to boiler system. •Utility cost reduction related to efficient equipment allowed building owners to reduce rental rates and more competitively attract tenants.	•Efficient boilers require more maintenance over their lifetime. Costs vary by boiler size.	•Boilers were not a separate category from HVAC in the Retrofit NEI study •The Retrofit NEI study showed positive NEIs for gas HVAC, while the NC NEI study showed negative NEIs for gas Boilers. •The difference is explained by the type of information capture by each study. •The NC NEI study considered operations and maintenance (O&M) costs over the life of each system, which were higher for efficient measures, while the Retrofit NEI study considered O&M costs over the one or two years that the systems had been installed prior to our interviews. •The Retrofit NEI study also assigned NEI values to increased rents, increased property values, and decreased administrative costs that the NC NEI study could not quantify for new buildings.
Comprehensive Design	•No comprehensive design measures.	•NEIs sources related to the technologies that comprised each comprehensive design measures.	•N/A
Compressed Air	•Equipment requires less frequent oil changes. •Avoided annual product loss due to compressor failures.	•Efficient equipment requires rebuilding and replacement of parts every 6-7 years versus every 3 years for baseline. •Equipment requires less frequent oil changes. •Zero-loss condensate drains avoid frequent filter replacements and treatment of oily condensate.	•Sources of NEIs are very similar between the NC NEI and Retrofit NEI studies. •NEIs were not calculated for compressed air in the Retrofit NEI study due to small sample sizes.
Food Service	•No food service measures.	•Reduced water usage. Decreased water and wastewater costs. •De-liming maintenance required less frequently. •Ovens and fryers have increased production capacity, steamers have decreased production capacity. •Efficient fryers require less maintenance, decreased oil replacement, less frequent oil filtration.	•N/A

New Construction versus Retrofit NEIs (Continued)

Technology	Retrofit NEI Sources	New Construction NEI Sources	Retrofit vs. New Construction NEI Comparison
Hot Water	•Switch to tankless water heater saved costs of EPA inspection for tank heater. •Fewer repairs needed after installation of efficient system. •Reduced labor costs after switch to instant hot water heater. Employees did not have to wait for hot water.	•Additional labor costs related to heat exchanger descaling and filter cleaning. •Fewer repairs required compared to baseline system.	•Hot water NEIs are positive for both the NC and Retrofit study •The NC NEI study calculated higher NEIs for hot water than the Retrofit NEI study, explained by differences in the size of repair and maintenance costs recorded by self-report interviews vs. the new construction engineering model.
Industrial Process	•Excess heat from water cooled manufacturing compressor used to eliminate other space heating.	•Electric injection molding machine does not require oil servicing.	•NEIs were not calculated for industrial process in the Retrofit NEI study due to small sample sizes.
Lighting	•Avoided light bulb and ballast changes. •Efficient lighting decreased staff time identifying burnt out bulbs. •Occupancy sensors eliminated twice daily building checks to make sure all lights are turned on and turned off. •Decreased electrical service contract price and number of contractor visits in buildings that rely on external instead of internal service. •Administrative hours saved processing contractor invoices, ordering bulbs, etc... •In warehouses, eliminated one stockroom FTE due to decreased bulb changes. •Savings related to disposing of fewer light bulbs.	•T5 bulbs are brighter than T8 bulbs, and can light a 20% larger space using the same number of fixtures. T5s results in fewer bulbs and fewer bulb changes. •LED fixtures require no maintenance in most cases, significantly reducing maintenance costs.	•Lighting NEIs were higher in the NC NEI study compared to the Retrofit NEI study. •Most of the bulbs installed during the NC study period were LEDs and T5s, which had very high maintenance savings, versus the T8 and T5 bulbs installed during the Retrofit study period, which had comparatively smaller maintenance savings.

New Construction versus Retrofit NEIs (Continued)

Technology	Retrofit NEI Sources	New Construction NEI Sources	Retrofit vs. New Construction NEI Comparison
Motors	•One respondent indicated that VFDs decreased frequency of needed system inspections.	•None	•Motors and Drives had slight positive NEIs under the Retrofit NEI study, but were not statistically significant.
Other Gas Heating	•All heating recorded under HVAC	•Infrared unit heaters are more costly to repair, and may require polishing reflector shield.	N/A
Refrigeration	•Systems require less maintenance. •Avoided significant food spoilage in food sales facilities.	•Efficient systems have longer useful life. •Systems require less maintenance. Compressor replacements are reduced from 2 to 4 years of the measure life. •Condenser lifetimes extended from 20 to 50 years.	•Refrigeration NEIs were very similar between the New Construction and Retrofit studies.
HVAC	•Systems require less maintenance. •Saved administrator hours overseeing contractor visits and repairs. •Utility cost reduction related to efficient equipment allowed building owners to reduce rental rates and more competitively attract tenants. •Equipment maintained building at more comfortable temperature, decreased tenant turnover. •Reduced product spoilage in food sales and food service facilities.	•Condensing furnaces require extra maintenance labor. •High efficiency units produce corrosive condensates, which may reduce durability. •Magnetic bearing chiller compressors require less frequent maintenance/oil changes. •Water cooled chillers last longer. •Chilled beams require less maintenance than fan coil boxes.	•HVAC NEIs were higher under the Retrofit NEI study compared to the NC NEI study. •The difference is explained by the type of information capture by each study. •The NC NEI study considered operations and maintenance (O&M) costs over the life of each system, which were higher for efficient measures, while the Retrofit NEI study considered O&M costs over the one or two years that the systems had been installed prior to our interviews. •The Retrofit NEI study also assigned NEI values to increased rents, increased property values, increased tenant comfort leading to decreased tenant turnover, reduced product spoilage in food sales buildings, and decreased administrative costs that the NC NEI study could not quantify for new buildings.

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Development and Application of Select Non-Energy Benefits for the EmPOWER Maryland Energy Efficiency Programs

Prepared by:

Itron, Inc.
11105 Inwood Avenue
Silver Spring, MD 20910
410-353-5491

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Introduction

The EmPOWER Maryland programs have been thoroughly evaluated and subjected to cost effectiveness testing throughout their five-year history. While other cost effectiveness screening tests have been reported, the Public Service Commission's cost effectiveness determination has generally focused on the Total Resource Cost (TRC) benefit cost test. The TRC is estimated at the program level, but, at least to date, the Commission has required only that sector level portfolios of each utility be cost effective.

To accurately reflect the net impacts of programs on utilities and utility customers, the TRC should capture and compare the present value of all participant, non-participant and utility benefits to the present value of all participant, non-participant and utility costs. In practice, the TRC analyses, in Maryland and elsewhere, more fully capture the costs associated with the programs than the benefits. A long list of non-energy benefits are usually omitted from energy efficiency program TRC analyses.

The EMPOWER programs ex post cost effectiveness analyses have included a few non-energy impacts, some of which improve and some of which diminish the cost effectiveness.[1] For example, the 2012 and 2013 analyses included:

- Incandescent lamp replacement costs for residential lighting measures – these increase the TRC benefits.
- Water and sewer bill reductions – these increase the TRC benefits.
- Reduction in natural gas and other heating fuel costs – these increase the TRC benefits.
- Increased natural gas costs resulting from reductions in waste heat from improved lighting efficiency -- these decrease the TRC benefits.

Among these benefits, only natural gas benefits have been included in previous ex ante cost effectiveness analyses used to develop the utilities' EmPOWER 3-year program plans. A 1.115 cent per kWh adder has been applied to the ex ante societal cost test (SCT) by four of the

[1] Itron conducted these analyses for the years 2009 through 2012 and has transferred the analysis over to Navigant starting with 2013. Henceforth, Itron will review and verify the cost effectiveness analyses as is done for the annual ex post evaluations.

EmPOWER utilities, but the SCT has to date received little attention from the Commission in its consideration of program or portfolio cost effectiveness.

The Commission and some stakeholders have been reluctant to expand the list of non energy benefits that are included in the TRC analyses. The overarching concern is that adding these benefits to the TRC will undermine its credibility with some stakeholders. This reluctance is primarily driven by the uncertainty associated with the estimating various non energy impacts. Some utilities have also expressed concern that counting additional benefits could be used to justify more program spending and thus increase EmPOWER surcharges, which appear on ratepayer bills.

There is merit to at least some of these concerns. With a few exceptions, it is not possible to directly measure or ascribe monetary values to non-energy impacts. Evidence of the uncertainty associated with many of the non energy impacts is the large variance in results found between different studies. There is also an understandable aversion to using scarce utility energy efficiency program dollars to pay for participating customers' increased comfort or other benefits that do not contribute to the broader societal goals that the EmPOWER programs were intended to achieve – e.g., reduced cost of electric services, reduced emissions, and the reduced need to build power plants or defer shut down of old plants.

However, concluding that valuation of non-energy benefits is an uncertain enterprise does not lead to the conclusion that the value of the non-energy impacts is zero. In fact, they are almost certainly not zero. Not including non-energy impacts in the cost effectiveness estimates ensures with great certainty that the cost effectiveness estimates are wrong.

Moreover, to be consistent, aversion to counting participant benefits in the TRC should be complemented by an aversion to counting participant costs. Granted, the EmPOWER programs were not intended to increase participant levels of comfort. But by the same token, neither were they intended to increase Marylanders' costs. Thus, aversion to counting participant benefits would seemingly lead to the conclusion that the TRC test is an inappropriate test for evaluating program cost effectiveness and would suggest greater emphasis be placed on alternative tests such as the Program Administrator Cost (PAC) test.[2]

In sum, as long as the TRC is the primary benefit cost test used for the EMPOWER programs, all benefits to utilities, participants and, we would argue, society more generally (i.e., non-participants), should be considered and included to the extent feasible. Rather than focusing on

[2] At least several major energy efficiency advocacy organizations have recommended greater emphasis on the PAC test instead of the TRC, because of unwillingness or inability to include more expansive set of participant non-energy benefits. Organizations making this argument include the American Council for an Energy Efficient Economy (ACEEE), the Regulatory Assistance Project (RAP), and the Northeast Energy Efficiency Partnership (NEEP).

uncertainty, the EmPOWER cost effectiveness analyses should focus on expected value. In order to accomplish this, four sets of questions should be asked:

1) Has a clear and conceptual case been made for the existence of the non energy impact?
2) Is the proposed non-energy impact valuation as likely to be too low as too high?
3) Is the proposed non-energy impact valuation the best available in terms of quality analysis and cost trade-off?
4) Are the analysts, sources and assumptions generally credible?

In this analysis, we develop estimates of selected non-energy impacts that could be included in the ex ante and/or ex post cost effectiveness analyses for the EmPOWER Maryland energy efficiency programs. We also, recommend values that based on our analysis we have concluded will improve the accuracy of future EmPOWER cost effectiveness analyses and better align those analyses with EmPOWER policy objectives.

Four non energy impacts are included in this analysis: air emissions, comfort, commercial operations and maintenance (O&M), and utility bill arrearages. In all four cases, we provide a recommended value and methods for including them in future EMPOWER costs effectiveness analyses. For these non energy impacts, we would argue that the answer to all four questions above is "yes."

The scope, methods and assumptions were reviewed and informed, but not directed, by the EmPOWER Cost Effectiveness Working Group. This Working Group draws on the expertise and perspectives of a diverse group of EmPOWER stakeholders, including Commission Staff, the Maryland Energy Administration, the EMPOWER utilities, the Office of Peoples Counsel, environmental organizations, and trade associations. While comments from the Working Group stakeholders greatly enhanced the quality of this analysis, the opinions in this report are the authors.

2

Air Emissions

2.1 Introduction

In this chapter, we examine the magnitude and potential methods for estimating air emissions benefits — associated with the EmPOWER programs. The focus is on uncompensated costs resulting from electricity consumption and the corresponding emissions associated with power generation -- specifically, carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NOx). More broadly, we assess the feasibility and rationale for incorporating environmental externality costs in EmPOWER program ex ante and/or ex post cost effectiveness analyses.

Externality costs arise when an activity imposes uncompensated costs on other people. Ideally, environmental externality costs would be eliminated through emissions controls or compensated through emissions taxes. If the costs to society of these air emissions are not eliminated or incorporated into the price of electricity, more electricity will be consumed than is economically efficient and there will be an underinvestment in research, development and implementation of energy efficiency improvements, alternative electricity supply resources, and emissions controls.

Reductions in damages from air emissions are benefits to the people who were bearing the externality costs and, arguably, should be counted as a benefit in EMPOWER program benefit cost analyses.

2.2 Air Emissions Background

The scope of this discussion is limited to NOx, SO_2, and CO_2. While these three air emissions comprise a large share of the environmental externality costs associated with electricity consumption, many other externality costs exist that are not discussed here, including: particulate emissions, other greenhouse gas emissions such as methane for gas pipeline leaks and sulfur hexafluoride used in electric transformers; the impacts of mercury or particulates from combustion of coal and gas; the impacts of coal, gas or uranium extraction and transportation; emissions from heating fuel savings; nuclear waste and coal ash disposal. These other costs are beyond the scope of this study but could be considered in the future.

2.2.1 Nitrogen Oxides

Nitrogen oxides (NOx) are emitted from combustion of gas, oil and coal by electric utilities, industrial boilers and motor vehicles. NOx is a major precursor, along with volatile organic compounds (VOC) for ground level ozone. High ozone levels causes and aggravates acute and chronic respiratory problems. Ground level ozone also affects crops and can cause premature aging of paint and rubber.[1]

NOx emissions from electric generators and other large sources are regulated as "criteria pollutants" along with ground level ozone levels under the federal Clean Air Act administered and enforced by the U.S. Environmental Protection Agency (EPA). Maryland's Healthy Air Act prescribed emissions regulations that became effective in 2007 and were intended to attain compliance with federal regulations. According to MDE, the Healthy Air Act has reduced NOx emissions in Maryland by about 70 percent relative to 2002.[2]

In 2014, the Maryland Department of Energy (MDE) is developing new power plant regulations to comply with even more stringent federal ground level ozone standards of 75ppb.[3] Meeting the standards is made more challenging because approximately two-thirds of the ground level ozone formation is caused by NOx emissions originating outside Maryland. While local controls can still help with attainment, tighter regional/national controls on interstate transportation of emissions are also seen as necessary by State officials.[4]

The State of Maryland also imposes permit fees (currently $54.29/ton) for EPA criteria pollutants and non-criteria hazardous air pollutants. These fees are paid by all large power plants (Title V sources), as well as smaller state permitted plants. In addition to the per ton fees, Title V emitters pay a $5,000 annual base fee and other smaller state-permitted plants pay a $1,000 annual fee. These fees collectively total only a few cents per MWh and are not a consequential cost component in Itron's analysis.

According to the Maryland Department of Environment, 2013 was the cleanest year for ground level ozone since record keeping began in 1980.[5] While weather is a significant factor in year to

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1 http://www.mde.state.md.us/programs/Air/AirandRadiationInformation/Pages/air/air_information/nitrogendioxide.aspx

2 See: http://www.mde.maryland.gov/programs/Air/Documents/GoodNewsReport2012/GoodNews2012finalinteractive.pdf.

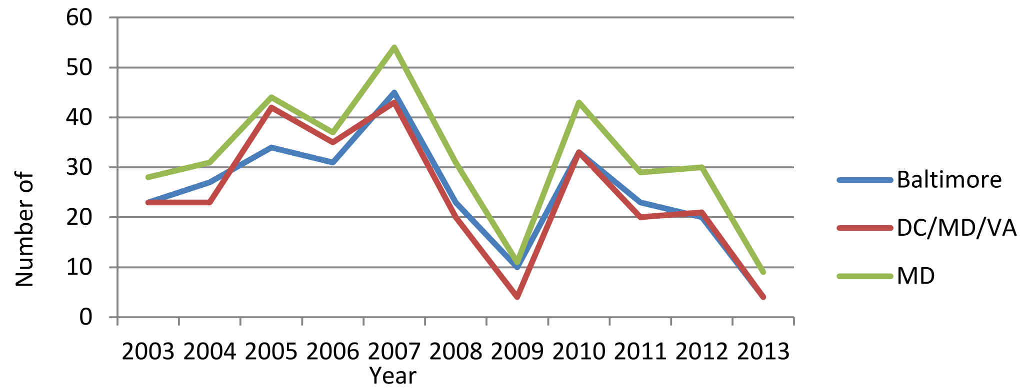
3 http://www.mde.state.md.us/programs/Air/Pages/MD_HAA.aspx#fed_comparison

4 Maryland Department of the Environment, "Meeting the New Ozone and Sulfur Dioxide Standards: What will it Take?," *2013 Power Plant Regulations Stakeholder Meeting*, October 21, 2013, p. 18.

5 Maryland Department of Environment, *Seasonal Report: 2013 Ozone*, viewed June 2, 2014, p.1, http://www.mde.state.md.us/programs/Air/AirQualityMonitoring/Documents/SeasonalReports/SeasonalReport_2013ozone.pdf

year variability in the number of non-attainment days for 8-hour ozone, the trend in the number of days generally seems to be declining, as shown in the figure below. The severity of non-attainment also seems to be on the decline (e.g., there have been no code purple days since 2006).[6] The improvements in ground level ozone correspond to significant reductions in statewide NOx emissions, which fell 70% between 2002 and ~~2012~~2013.[7]

Figure 2-1: Number of 8-Hour Ozone Exceedance Days



Source: Based on data from MDE, Historical Air Quality Data, downloaded June 2, 2014.

While air quality in Maryland has generally improved, Maryland still has room for improvement. The average number of non-attainment days was 25 in the previous five-year period 2008-12.[8] Baltimore has not even met the old pre-2008 one-hour standard for ozone of 85 ppb and is the only location in the Eastern United States that is still designated a "moderate" non-attainment area; other locations in the East are designated, at worst, "marginal" non- attainment areas.[9]

Moreover, meeting federal clean air requirements does not mean that ozone levels emissions have reached safe levels. While the current regulations were ultimately set at 75 ppb, the EPA's Clean Air Scientific Advisory Committee recommended ozone requirements of 60 ppb and 70

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6 Sunil Kumar, *Ozone Season Summary 2013*, power point presentation to Metropolitan Washington Area Council of Governments, June 11, 2013, p.4.

7 See: http://www.mde.maryland.gov/programs/Air/Documents/GoodNewsReport2012/GoodNews2012finalinteractive.pdf.

8 Maryland Department of Environment, *Seasonal Report: 2013 Ozone*, viewed June 2, 2014, p.1, http://www.mde.state.md.us/programs/Air/AirQualityMonitoring/Documents/SeasonalReports/SeasonalReport_2013ozone.pdf

9 See Maryland Department of Environment, Emission Reduction Credits Frequently Asked Questions, http://www.mde.maryland.gov/programs/Permits/AirManagementPermits/ERC/Pages/index.aspx. The Baltimore Region includes: Anne Arundel, Baltimore, Carroll, Harford and Howard Counties, along with Baltimore City.

ppb and stated that further benefits could be achieved at these more stringent levels.[10] The American Lung Association, which argues that the 2008 federal ozone standard is not stringent enough to protect human health, gave all but one of the 14 counties it graded an "F" for ozone in its 2013 State of the Air Report, making Maryland one of the worst states in the nation on this metric.[11]

Finally, while Maryland has been aggressive in reducing emissions of nitrogen oxides, roughly 70% of the nitrogen oxide emissions in Maryland come from outside the State, much of it generated within the PJM. To the extent that EmPOWER programs reduce PJM generation, they could also impact in-State nitrogen oxide levels.

2.2.2 Sulfur Dioxide Emissions

Sulfur Dioxide (SO_2) is emitted from fuel burning sources including electric utilities, industrial boilers, and vehicles. SO_2 emissions are a major contributor to fine particle pollution, thus increasing the severity of respiratory diseases. SO_2 emissions also react with water to cause acid rain, contributing to the acidification of forests and waterways and damaging vegetation and depleting fish populations.[12]

SO_2 emissions from electric generators and other large sources are regulated under the federal Clean Air Act. Maryland's Healthy Air Act prescribed emissions regulations that are the most stringent of any State on the East Coast. According to MDE, the Healthy Air Act has reduced SO_2 emissions in Maryland by about 80 percent relative to 2002.[13]

EPA requirements call for concentrations of no more than 75 ppb measured over one hour compared to the previous standard of 140 ppb averaged over 24 hours. The level of effort required to meet the EPA emission requirements is unknown since areas in Maryland, like most other parts of the country, have not yet been designated attainment or non-attainment. MDE is developing regulations and other early actions that can be taken to avoid areas in Maryland being

10 Maryland Department of the Environment, "Meeting the New Ozone and Sulfur Dioxide Standards: What will it Take?," *2013 Power Plant Regulations Stakeholder Meeting*, October 21, 2013, p. 15.

11 American Lung Association, State of the Air 2013, p.99, http://www.stateoftheair.org/2013/assets/ala-sota-2013.pdf. The study is based on EPA air quality data for the three year period 2009 to 2011.

12 http://www.mde.maryland.gov/programs/pressroom/documents/sulphur.pdf

13 See: http://www.mde.maryland.gov/programs/Air/Documents/GoodNewsReport2012/GoodNews2012finalinteractive.pdf.

designated non-attainment areas by EPA. MDE has stated publicly that this will require additional focus on SO_2 from electric power plants and other large stationary sources.[14]

SO_2 emissions, like NOx and other criteria and hazardous non-criteria pollutants, are subject to permit fees (currently $54.29/ton) and annual base fees (see NOx, above). As mentioned above, these fees collectively total only a few cents per MWh and are not a consequential cost component in Itron's analysis.

Approximately 99% of the damages associated with SO_2 result from the transformation of SO_2 into coarse and fine particulates -- PM_{10} and $PM_{2.5}$, respectively. Significant reductions in SO_2 emissions have been achieved in Maryland with attendant improvements in the air quality of many areas of the State. As far back as 1997, most counties west of the Chesapeake Bay had been designated non-attainment areas for $PM_{2.5}$ by EPA. In 2013, MDE applied to EPA to have many of those counties redesignated as attainment areas, including Baltimore City and Anne Arundel, Baltimore, Carroll, Harford, Howard, and Washington counties.[15]

Likewise, the acidification of forests and streams has been largely mitigated by reductions in SO_2 emissions over the last two decades. At one time, Maryland's waterways and forests were exposed to some of the highest concentrations of sulfur dioxides in the United States. There seems to be little concern at this point about continued acidification of Maryland forests and waterways. A 2011 report of the National Science and Technology Council (NTSC) touts the significant human health benefits that have resulted from SO_2 (and NOx) emissions reductions and reports that some acid-sensitive areas are even showing signs of recovery. [16]

While reductions in SO_2 emissions have had significant and lasting effects on Maryland people and ecosystems, at least four counties (including the two largest by population) still remain on the EPA's non-attainment list for fine particulates ($PM_{2.5}$), namely: Montgomery, Prince Georges, Frederick, and Charles counties. In addition, the same NTSC Report that touted the major gains that have been made with respect to acid rains also concluded that additional

[14] Maryland Department of the Environment, "Meeting the New Ozone and Sulfur Dioxide Standards: What will it Take?," *2013 Power Plant Regulations Stakeholder Meeting*, October 21, 2013, pp. 11, 29.

[15] Maryland Department of the Environment, Baltimore Nonattainment PM2.5 Redesignation Request, prepared for the U.S. Environmental Protection Agency, May 28, 2013, http://www.mde.state.md.us/programs/Air/AirQualityPlanning/Documents/PM2.5%20Redesignation%20Requests%20and%20Maintenance%20Plans/Baltimore%20NAA/Baltimore%20PM%20RR%20FINAL.pdf. And Maryland Department of the Environment, Washington County Nonattainment PM2.5 Redesignation Request, prepared for the U.S. Environmental Protection Agency, May 28, 2013, http://www.mde.state.md.us/programs/Air/AirQualityPlanning/Documents/PM2.5%20Redesignation%20Requests%20and%20Maintenance%20Plans/Washington%20County%20NAA/WashCo%20PM%20RR%20FINAL.pdf

[16] National Science and Technology Council, National Acid Precipitation Assessment Program Report to Congress: An Integrated Assessment, 2011, p. 87.

emission reductions are necessary in order to protect and further aid in the recovery of acid-sensitive ecosystems.[17]

2.2.3 Carbon Dioxide Emissions

Carbon dioxide emissions are emitted from the combustion of fossil fuels. Carbon dioxide is a major greenhouse gas, the main anthropogenic cause of global warming. Generation of electricity is the single largest source of CO_2 emissions. Maryland is particularly vulnerable to both the impacts of climate change – having the fourth longest coastline of any state – and the cost of abatement – more than 40% of electric consumption is generated from coal. Coal generation releases about twice as much CO_2 per Btu into the atmosphere as natural gas, with petroleum in between.

Historically, federal and state regulation of CO_2 has been minimal. Maryland has been a member of the Regional Greenhouse Gas Initiative (RGGI) since its inception in 2009. RGGI is a CO_2 cap and trade program in which member states commit carbon dioxide emission caps for electric power generators. Unlike most cap and trade regime, RGGI distributes allowances primarily through auctions – 94% of RGGI allowances through 2013 had been distributed via auctions. The RGGI caps to date have generally been non-binding – i.e., allowances have exceeded actual emissions.[18] This could change as a new model rule announced in 2012 will lower the RGGI caps by 2.5 percent annually through 2020.[19]

Despite the nonbinding caps, since the inception of RGGI in 2008, auction clearing prices for Maryland allowances have averaged $2.55 per ton. The new and more stringent caps under the new model rule have driven RGGI auction prices sharply higher. The Maryland clearing prices since the new model rule was announced have averaged $3.21 per ton and the latest auction cleared at $5.02 per ton. Through June 2014, Maryland cumulative proceeds from RGGI allowance auctions were $364 million. These revenues have been used to fund a variety of energy efficiency programs, alternative energy investments, abatement related activities, and

[17] National Science and Technology Council, National Acid Precipitation Assessment Program Report to Congress: An Integrated Assessment, 2011, p. 87.

[18] RGGI, Inc., *RGGI 2012 Program Review: Summary of Recommendations to Accompany Model Rule Amendments*, p.1, http://www.rggi.org/docs/ProgramReview/_FinalProgramReviewMaterials/Recommendations_Summary.pdf, viewed June 2, 2014. The RGGI allowance auctions have still generated proceeds because of an auction floor price, however. RGGI, Inc. claims reductions from investments of 2009-12 auction proceeds will reduce greenhouse gas emissions by 8 million short tons over the lives of the various measures.

[19] RGGI, Annual Report on the Market for RGGI CO2 Allowances: 2013, prepared by Potomac Economics, May 2014, p.5, http://www.rggi.org/docs/Market/MM_2013_Annual_Report.pdf.

energy bill assistance.[20] The allowance clearing price represents, in effect, a tax on CO_2 emissions.

More powerful regulations on electric carbon emissions could be forthcoming. Most notably, on June 2, 2014, EPA issued a proposed rule that would reduce CO_2 emissions from the power sector from 2005 levels by 30% by 2030. Our preliminary review suggests the proposed rule would establish a 2030 Maryland goal of 1,187 lbs. CO_2 per net MWh, which is more than a 30% reduction from 2013 levels (over 1700 lbs. per net MWh).[21] While much of the reductions in power plant carbon intensity will have to come from coal to gas conversion or plant retrofits, the proposed rule would allow a portion of the required reductions in power plant emissions intensity to be offset by energy efficiency improvements and investments in renewable energy.[22]

The federal carbon regulations will presumably require some additional emissions reductions in Maryland beyond those that will already be induced by the new RGGI caps. Given the carbon regulations are only "proposed" at this point and will be the subject of intense scrutiny and political wrangling in the coming months or years, derivation of an associated carbon price or compliance costs was beyond the scope of this analysis

2.3 Methods and Data

The following equation summarizes our estimation of EmPOWER air emissions benefits:

> *Air Emissions Benefits = MWh Savings x Emissions Intensity (lbs/MWh) x [Unit Damage Costs ($/lb) – Unit Emissions Taxes/Fees Paid by Utilities ($/lb)] = Total Benefits ($)*

We calculate Total Benefits separately for NOx, SO_2, and CO_2. Benefits per kWh are then estimated:

> *Benefits per kWh ($/kWh) = Total Benefits ($) / [Total MWh Savings (MWh) x 1000]*

Finally, we look at the impact of including the air emissions benefits on the 2011 Total Resource Cost Benefit-Cost estimates (TRC B/C).

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[20] http://www.rggi.org/docs/Auctions/23/MD_Proceeds_By_Auction.pdf

[21] For Maryland requirements see US Environmental Protection Agency, Carbon pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 40 CFR Part 60, RIN 2060, p.64, AR33 http://www2.epa.gov/sites/production/files/2014-05/documents/20140602proposal-cleanpowerplan.pdf. Current emissions are based on data from Luke Wisniewski, Maryland Department of Environment received March 14, 2014.

[22] The EPA requested comments, due 120 days after publication, and is holding a series of workshops across the country on the proposed rule.

2011 TRC B/C with Air Emissions Benefits = [2011 Electric and Non-Electric Benefits ($) + Air Emissions Benefits ($)] / 2011 Program and Participant Costs

We describe the methods and data used to develop inputs for each of the equation parameters below.

2.3.1 MWh Savings

The scope of this emissions reductions analysis is limited to evaluated MWh savings from the utility-administered EMPOWER energy efficiency programs. ~~The 2013 verification was not finalized in time for this analysis, thus~~ Program Year ~~2012~~ 2013 evaluated savings are used. The ~~2012~~ 2013 programs included:

- Commercial and Industrial: Prescriptive, Small Business ~~and~~ , Custom and Multifamily Master Metered (PEPCO only).
- Residential: Lighting, HVAC, Appliance Rebates and Recycling, Home Performance with Energy Star, Quick Home Energy Check Up, and New Construction.

The limited income programs are not included since they were not evaluated and verified in ~~2012~~time for this analysis. For the air emissions analysis, exclusions of the limited impact programs will not have a material impact on any of the results. The cents per kWh air emissions benefits estimated in this analysis can be applied to any program's electric savings.[23]

~~The analysis can be readily updated to reflect 2013 verified savings once they are finalized. Using the 2013 verified savings will increase the total air emissions benefits since the MWh savings was higher in 2013 than 2012. We do not expect it to materially affect the dollars per kWh air emissions benefits, nor the percentage impact on the Total Resource Cost estimates.~~

2.3.2 Emissions Intensity

Emissions intensities data were obtained from PJM Environmental Information Services Electricity Generation Attribute Tracking System (EGAT). EGAT data provides SO_2, NO_x and CO_2 emissions associated with PJM MWh generation by fuel type. These data are available for the years 2005 through 2013.[24]

[23] One exception to this would be for programs that are specific to obtaining peak savings. For these programs, the generation mix of avoided energy would be different than the average generation mix used in the current analysis. Because peak generation is "dirtier" than average, applying the air emissions benefits estimated in this analysis to peak programs would result in conservative avoided damage cost estimates.

[24] https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix

Our calculations implicitly assume that the EmPOWER MWh reductions coincide with the PJM average generation profile. The major factor driving our decision to use average generation mix rather than peak generation fuel mix is that we have no reason to think the EmPOWER MWh reductions are likely to affect peak loads more than base or intermediate loads. Based on discussions with the statewide evaluator, the utilities and others, we heard no arguments that peak generation fuel mix should be used.

All other things equal, using the average PJM average generation profile likely results in an underestimate of emissions. The PJM average generation profile is far less coal and fossil intensive than the marginal generation profile. As shown in the table below, marginal coal and fossil fuel percentages for 2012 and 2013 were significantly higher than the corresponding average generation percentages.

Table 2-1: Comparison of Average Coal and Fossil Generation MWh to Real-Time Marginal Units (% of Total Generation)

	Fuel	2012	2013
Average generation mix	**Coal**	42%	44%
	Fossil	62%	61%
Marginal generation mix	**Coal**	59%	58%
	Fossil	95%	95%

Sources: PJM, State of the Market Report: 2013, Table 3-6 and PJM Generation Attribute System, https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix.

2.3.3 Unit Damage Costs – NOx and SO_2

Our NOx and SO_2 damage cost inputs are based on National Academy of Sciences (NAS) *Hidden Costs* Study from 2010.[25]

Hidden Costs Study Method and Results

The *Hidden Costs* study is the only recent peer reviewed environmental externalities study with significant analytical support and potential applicability to the Maryland electric sector that we are aware of. The *Hidden Costs* study examined and estimated a wide range of externality costs associated with energy production and use, including electricity and fuels. It was funded by the US Department of the Treasury and was guided by more than 30 senior economist and other experts.

[25] National Research Council Study, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption*, 2010.

The *Hidden Costs* analysis of electricity generation was based on plant emissions data from the National Emissions Inventory of 406 coal-fired and 498 gas-fired power plants in 2005. Monetized damages per ton of EPA criteria pollutant were estimated using the Air Pollution Emissions Experiments and Policy (APEEP) model, which calculates the monetized damages resulting from exposure by populations to various pollutants.[26]

The vast majority of air emissions damages were related to health impacts and mortality was by far the largest category of heath impacts.[27] Other health impacts included chronic bronchitis, asthma, emergency hospital admissions for respiratory and cardiovascular disease. While impacts on visibility, crop and timber yields, buildings and infrastructure, and recreation were also considered, they were small in comparison to health impacts. Some ecosystem damages were not estimated, including impacts of acid rain from SO_2 and NOx on forests and fish populations and the eutrophication of water ecosystems from nitrogen deposition.[28]

Table 2-2: APEEP Value of Human Health Effects*

Health Event	Unit	U.S. Dollars
Chronic Exposure Mortality	Case	5,910,000
Chronic Bronchitis	Case	320,000
Chronic Asthma	Case	30,800
General Respiratory	Hospital Admission	8,300
General Cardiac	Hospital Admission	17,526
Asthma	Hospital Admission	6,700
COPD	Hospital Admission	11,276
Ischemic Heart Disease	Hospital Admission	18,210
Asthma	ER Visit	240

[a]Values are in 2000 U.S. dollars; see Muller and Mendelsohn 2007.

SOURCE: Modified from Muller and Mendelsohn 2006.

* National Research Council Study, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption*, 2010, Appendix C, p.428.

Health impacts were calculated using concentration-response functions employed in regulatory impact analyses by EPA. A variety of non-market valuation studies were used for other health impacts. Human mortality was valued using EPA's statistical value of a life, equal to about $6

[26] For a detailed description of the APEEP model and its relative strengths and weaknesses, see National Research Council Study, *Hidden Costs of Energy*, pp. 64-125 and pp. 423-31.

[27] Ibid, p. 84.

[28] Ibid, p. 85.

million, as shown in the table above, which reports the values attributed to various chronic and acute health events.[29]

The concentration response functions and valuation of mortality are two major sources of uncertainty with respect to these types of damage cost estimates. The dominance of human mortality in the damages estimates makes the results sensitive to the mortality valuation. If a human life was valued at $2 million rather than $5.9 million, for example, the weighted average damages from coal would be about two-thirds lower.[30] On other hand, if another popular concentration response model had been used, the damages would have been three times higher.

The tables below presents the Hidden Cost Study estimates of monetized damages per kWh from 2005 vintage coal and gas generation. As shown, per kWh damages associated with various plants throughout the United States vary widely. Most notably, for coal plants the SO_2 per kWh damages of plants in the top 95th percentile were 50-times the damages of the bottom 5^{th} percentile. For gas plants, NOx emissions in the top 95th percentile were 714-times the damages of the bottom 5^{th} percentile.

[29] Note that mortality estimates do not include deaths of workers in coal or gas production or distribution, since these valuations are assumed to be included in the wages charged by labor and passed through to electricity prices.

[30] National Research Council Study, *Hidden Costs of Energy*, pp. 93-95.

Table 2-3: Distribution of Criteria Air Pollutant Damages per Kilowatt-Hour Associated with Emissions from 406 Coal-Fired Power Plants in 2005 (2007 Cents)

	Mean	Standard Deviation	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
SO_2	3.8	4.1	0.24	1.0	2.5	5.2	11.9
NO_x	0.34	0.38	0.073	0.16	0.23	0.36	0.91
$PM_{2.5}$	0.30	0.44	0.019	0.053	0.13	0.38	1.1
PM_{10}	0.017	0.023	0.001	0.004	0.008	0.023	0.060
Total (equally weighted)	4.4	4.4	0.53	1.4	2.9	6.0	13.2
Total (weighted by net generation)	3.2	4.3	0.19	0.71	1.8	4.0	12.0

NOTE: In the first five rows of the table, all plants are weighted equally; that is, the average damage per kWh is 4.4 cents, taking an arithmetic average of the damage per kWh across all 406 plants. In the last row of the table, the damage per kWh is weighted by the electricity generated by each plant to produce a weighted damage per kWh.

ABBREVIATIONS: SO_2 = sulfur dioxide; NO_x = oxides of nitrogen = PM, particulate matter.

National Research Council Study, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption*, 2010, Table 2-9, p.92

Table 2-4: Distribution of Criteria-Pollutant Damages per Kilowatt-Hour Associated with Emissions from 498 Gas-fired Power Plants in 2005 (Cents based on 2007 U.S. Dollars)

	Mean	Standard Deviation	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
SO_2	0.018	0.067	0.00013	0.00089	0.0022	0.006	0.075
NO_x	0.23	0.74	0.0014	0.013	0.038	0.16	1.0
$PM_{2.5}$	0.17	0.56	0.00029	0.007428	0.026	0.08	0.75
PM_{10}	0.009	0.029	0.00003	0.00043	0.0014	0.0042	0.036
Total (unweighted)	0.43	1.2	0.0044	0.041	0.11	0.31	1.7
Total (weighted by net generation)	0.16	0.42	0.001	0.01	0.036	0.13	0.55

NOTE: In the first five rows of the table, all plants are weighted equally; that is, the average damage per kWh is 0.43 cents, taking an arithmetic average of the damage per kWh across all 498 plants. In the last row of the table, the damage per kWh is weighted by the fraction of electricity generated by each plant to produce a weighted damage per kWh.

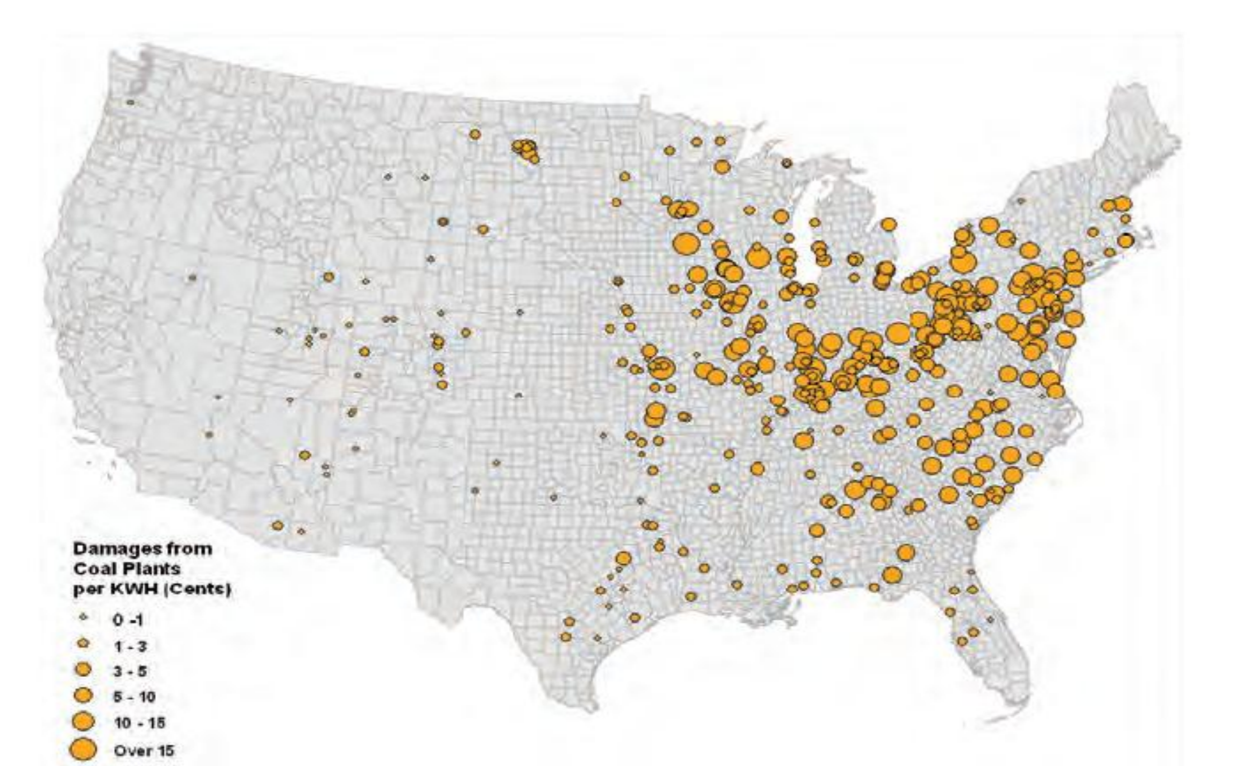
ABBREVIATIONS: SO_2 = sulfur dioxide; NO_x = oxides of nitrogen; PM = particulate matter.

National Research Council Study, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption*, 2010, Table 2-15, p.118.

For our analysis, we multiplied the mean per kWh damages for each emissions type by the ratio of the total weighted average to the total simple average. This was intended to approximate the weighted average damages per kWh for each emission type. While we did not have access to the individual plant results from the Hidden Cost Study, the figures show the geographic distribution of damages per KWh for plants included in the NAS study., These figures suggest that, if anything, the weighted mean probably understates the per kWh damages associated with PJM coal and gas plants in 2005 due to the relatively higher concentration of large damage cost plants in the PJM service territory.[31]

[31] Admittedly, the figures provide only modest support for this claim. The study team did have access to the county level damage cost estimates used in the NAS study. An attempt was made to combine these county level data with EPA emissions data from every coal and gas fired generator in PJM territory (http://epa.gov/cleanenergy/energy-resources/egrid/index.html) to form a fully custom emissions analysis.

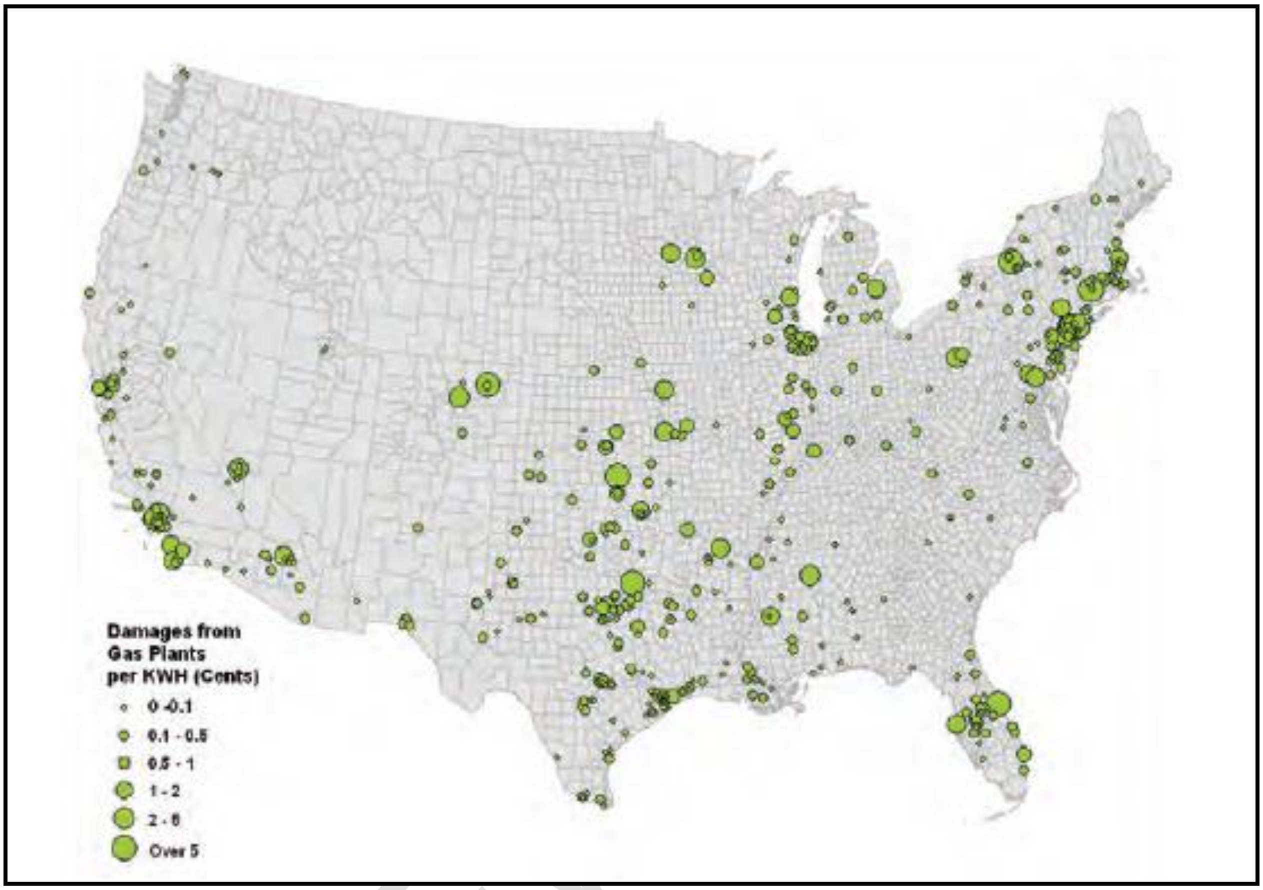
Figure 2-2: Regional Distribution of Air Pollution Damages from Coal Generation per kWh in 2005 (U.S. dollars, 2007) *



National Research Council Study, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption*, 2010, Figure 2-2, p.118.

However, this analysis is not included because the emissions data obtained from the EPA did not reconcile with system wide emissions reported by PJM, presumably due to the inclusion of energy imports. Although the study team believes the damage estimates presented in this analysis to be conservative, the wide variability in damages indicated in Table 2-3 and Table 2-4 may justify a more robust county level analysis in the future.

Figure 2-3: Regional Distribution of Criteria-Air-Pollutant Damages for Gas Generation per kWh (U.S. dollars, 2007)



National Research Council Study, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption*, 2010, Figure 2-17, p.122

Changing Emissions Intensity

Our analysis further adjusts the *Hidden Costs* coal plant value to account for dramatic reductions in NOx and SO_2 emissions intensity that have occurred since 2005. Total environmental externality damages associated with NOx and SO_2 have been significantly reduced in recent decades through regulations requiring emissions reductions and other policies. Maryland utilities alone have invested $2.6 billion in pollution controls to comply with the Healthy Air Act.[32] Our

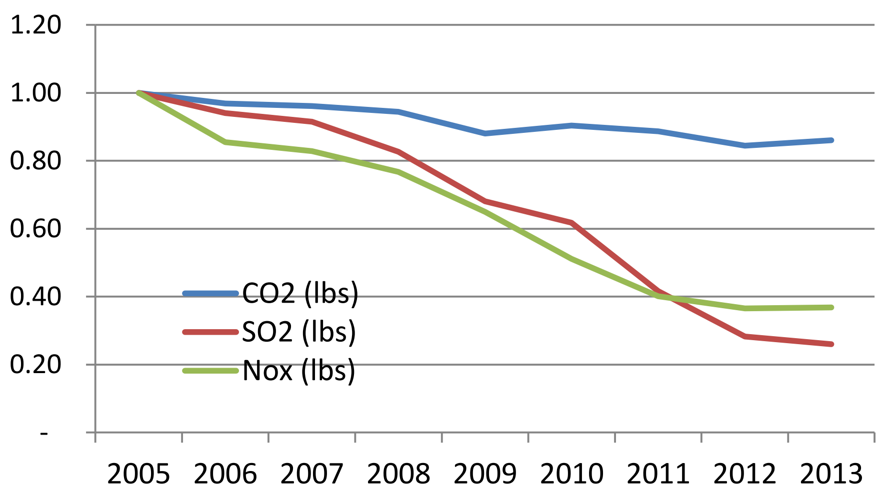
[32] Maryland Department of the Environment, *Clean Air Progress in Maryland 2012*, p.6, http://www.mde.maryland.gov/programs/Air/Documents/GoodNewsReport2012/GoodNews2012finalinteractive.pdf.

analysis reflects both historical and projected future reductions in emissions and emissions intensities (emissions per MWh) from coal and gas generators.

Overall Emissions Intensity

As shown in the figure below, for the PJM generation mix as a whole, 2013 SO_2 and NOx emissions per MWh were two thirds to three fourths lower than in 2005. CO_2 emissions per MWH fell as well, though not nearly so dramatically.

Figure 2-4: PJM Emissions per Total MWH, 2005–2013



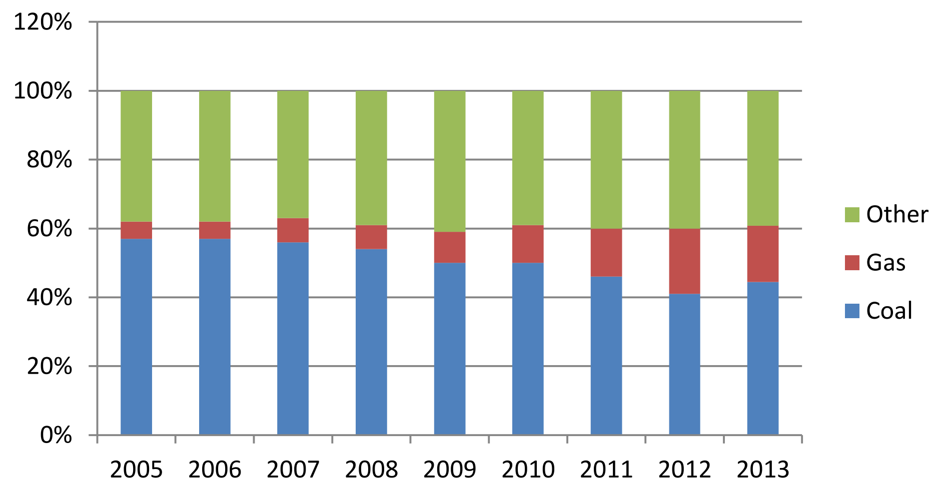
Source: Itron calculations based on PJM Environmental Information

Emissions reductions can result from a number of factors including changes in fuel mix, additional emissions controls, improved plant efficiencies and fuel quality. To make adjustments to the Hidden Costs values, we needed to understand the sources of the reduced emissions intensities.

Generation Fuel Mix

The following figure shows how PJM fuel shares of coal and gas changed from 2005 thru 2013. Together, gas and coal have maintained a roughly 60% share of total MWH generation, but their respective shares have changed significantly. Gas generation increased from just 5% of overall generation in 2005 to 16% in 2013, while coal generation went from 57% to 44%. Even if no emissions controls were adopted, these fuel mix changes alone would have enormous impact on criteria and CO_2 emissions; natural gas combustion results in roughly half the CO_2 emissions of coal and produces a relatively trivial amount of SO_2 emissions.

Figure 2-5: Changing Shares of Coal and Gas Generation in PJM, 2005–2013

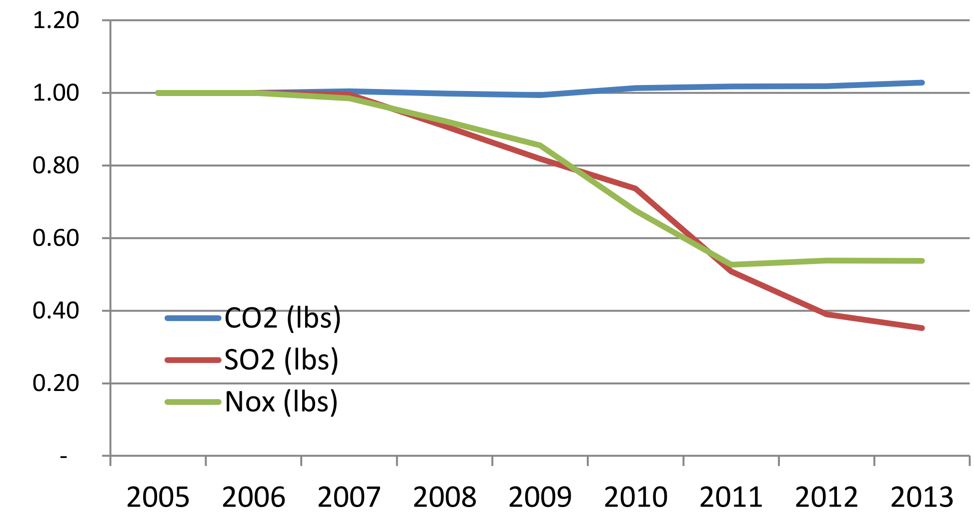


Source: Itron calculations based on PJM Environmental Information Services Electricity Generation Attribute Tracking System

<u>*Plant Emissions Intensity*</u>

Plant emissions intensities can change as a result of increased emissions controls, changes in the quality of fuels, and/or plant efficiency improvements. For economic as well as regulatory reasons, most reductions in plant emissions intensity are the result of new plants coming on line, though some may be the product of existing plant retrofits. The following two figures show the marked improvements that have been made from emissions controls and improved plant efficiencies for PJM's coal and natural gas generation, respectively.

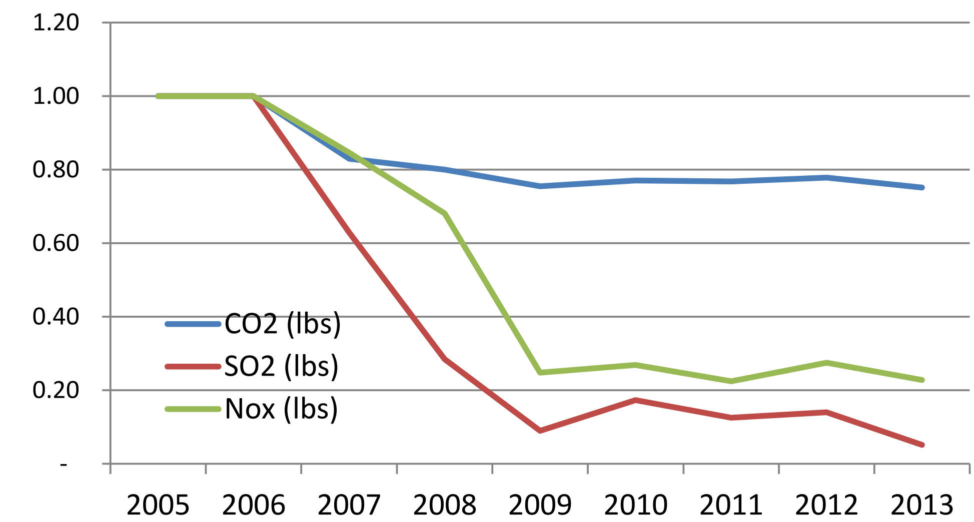
Figure 2-6: PJM Coal Generation Emissions per MWh, 2005–2013



Source: Itron calculations based on PJM Environmental Information Services Electricity Generation Attribute Tracking System

Criteria emissions per MWh generated from coal plants in 2013 were roughly one half of 2005 levels. The emissions intensity reductions are mostly from emissions controls. The use of sub-bituminous (i.e., low sulfur) coal contributed some to the reduction; it was nine percent of coal generated MWH in 2005 and 13 percent in 2013. The CO_2 trend line indicates little if any improvement in the efficiency (lower Btu input per MWH) of the coal plant fleet.

Figure 2-7: PJM Gas Generation Emissions per MWh, 2005–2013



Source: Itron calculations based on PJM Environmental Information Services Electricity Generation Attribute Tracking System

Criteria emissions per PJM MWh generated from gas plants in 2013 were only about one fifth of 2005 levels. The CO_2 trend line suggests roughly one fourth of the reduction in criteria emissions intensity was the product of more efficient plants (lower Btu input per MWH) coming on line and to a lesser degree retrofits of existing plants. The bulk of the emissions intensity reductions are from more stringent emissions controls requirements.

Adjustments to Hidden Costs Study Cost Estimates to Account for Past Changes in Emissions Intensity

The table below shows the changes in PJM emissions intensity (lbs per MWh) that have resulted from plant improvements and fuel switching for each fuel in 2013 compared to 2005, the year upon which the *Hidden Costs Study* damage cost estimates were based. Our analysis reflects these changes.

Table 2-5: Emissions Intensity 2013 as Percent of 2005

Gen Fuel	NOx	SO_2	CO_2
Coal	54%	35%	103%
Gas	23%	5%	75%

Source: Itron calculations based on PJM Environmental information Service data, https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix

2.3.4 Adjustments for Future Changes in Emissions Intensity

The Hidden Costs Study projected damage costs per kWh out to 2030 using Energy Information Administration projections of national electricity consumptions increases and emissions decreases. For both coal and gas, damages per kWh in 2030 were expected to be lower than in 2005 as increases in damages per ton resulting from population growth and growing wages (affecting statistical value of life) were expected to be more than offset by emissions intensity reductions. Coal plant damages per kWh in 2030 were expected to be 40% lower than 2005 damages per kWh. Damages per kWh from gas generation were expected to be 32% lower in 2030.[33]

Above we described adjustments that we made to the Hidden Costs Study damage costs per kWh values to reflect historic reductions in gas and coal SO_2 and NOx emissions intensity from 2005 thru 2013. Those adjustments already far exceed the 2030 projections of the Hidden Costs

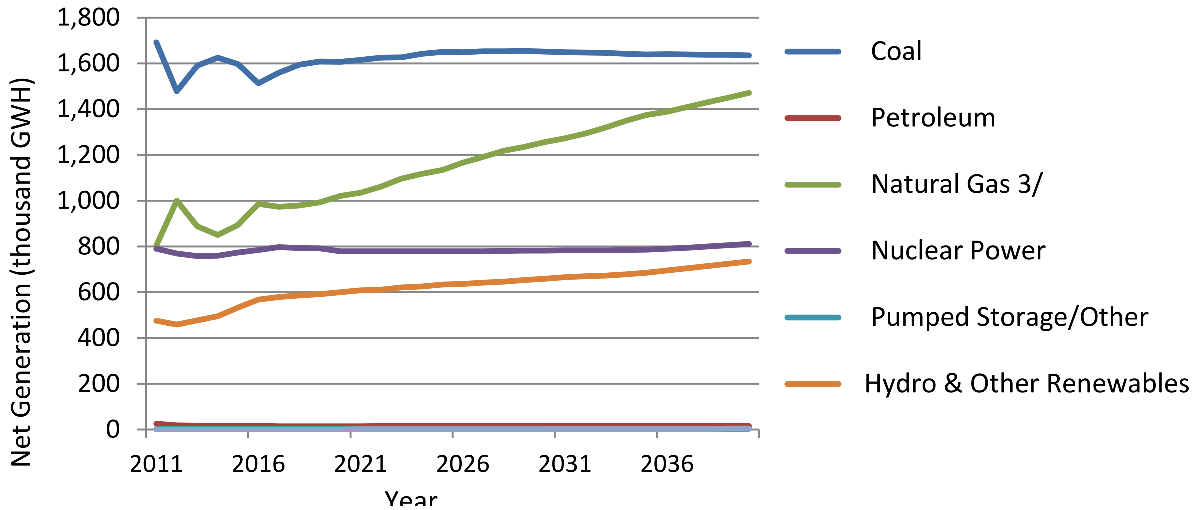
33 National Research Council Study, *Hidden Costs of Energy*, pp. 104-109 for discussion of coal generation projections and pp. 124-5 for gas generation.

Study. Nevertheless, additional adjustments were still needed to reflect projected changes in fuel mix and corresponding change in aggregate emissions intensities.

We do not adjust for future improvements in emissions intensity resulting from emissions controls since those will presumably result in additional costs to utilities, which will be included in future avoided costs projections. In other words, reductions in damage costs will be partially offset by increased emissions control costs.

Damage costs resulting from changes in the generation fuel mix would not be captured in utility avoided cost projections, however. As shown in the figure below, EIA projects significant increases in natural gas generation and hydroelectric and other renewable resources, while coal and nuclear generation are expected to remain roughly flat.

Figure 2-8: U.S. Projected Net Generation through 2040



Source: Data from Energy information Administration, *Annual Energy Outlook 2014*, Table A8.

Between 2013 (the last year we adjusted for) and 2024 (the projected weighted average life of measures in the 2014 portfolio is ~~10~~ 12 years) , the share of coal nationally is expected to go from 43% of total generation down to 39%, while gas is projected to increase from 24% to 27%.[34]

Assuming proportional changes in the PJM fuel mix decreases the estimated SO_2 emissions per kWh by six percent. Projected fuel mix changes reduce estimated NOx damages per kWh by five percent and CO_2 damages by less than one percent.

[34] Source: Data from Energy Information Administration, *Annual Energy Outlook 2014*, Table A8.

2.3.5 Criteria Pollutant Damages per kWh Values Used in Our Analysis

The table below adjusts the *Hidden Costs* damages per kWh values to reflect the discussions above. In sum, the adjustments include: 1) conversion from simple average to weighted average damage costs, 2) historical 2005-2013) reductions in emissions intensity, and 3) converts the *Hidden Costs* damages from 2007 dollars to 2013 dollars. As shown, the SO_2 and NOx damages per kWh used for our analysis are only a fraction of the values from the *Hidden Costs* Study.

Table 2-6: Summary of Criteria Emissions Unit Damage Calculations

	Hidden Costs Simple Average cents/kWh Damages ($2007)		**Ratio of Total Weighted Average to Average $/kWh**	**Weighted Average cents/kWh Damages ($2007)**		**Ratio 2013 to 2005 Emissions Intensity**		**Adjusted Damages cents per kWh ($2007)**		**Adjusted Damages cents per kWh ($2013)**	
Type	**NOx**	**SO_2**	**Combined**	**NOx**	**SO_2**	**NOx**	**SO_2**	**NOx**	**SO_2**	**NOx**	**SO_2**
Coal	0.34	3.8	73%	0.25	2.76	54%	35 %	0.13	0.97	0.15	1.12
Gas	0.23	0.02	37%	0.09	0.01	23%	5%	0.02	0.00	0.02	0.00
Sources	Calc NAS, Tables 2-9 & 2-15			Calc		Calc PJM EIS		Calc		Calc CPI	

As a final note, the *Hidden Costs* study estimates of damages per kWh are a function of emissions per kWh (emissions intensity) and the dollar damages per ton of emissions. For both coal and gas plants, emissions per kWh are the dominant driver of the damages per kWh values. Emissions per kWh are a function of fuel quality (e.g., high versus low sulfur coal), emissions controls and the plant age. Damages per ton of emissions are a function of the plant's proximity to population centers and stack heights.[35]

As discussed above, we adjusted for changes in emissions per kWh since 2005 and for projected changes through 2024. We did not adjust values for damages per kWh to reflect changes subsequent to 2005 in damages per ton of emissions. In other words, we assume that the damages per ton are independent of the number of tons. According to the Hidden Cost Study this is consistent with the epidemiological literature and with EPA calculations, which assume that damages per ton of emissions are constant throughout the relevant ranges of values.[36] While we accepted this assumption for our current analysis, this assumption should be tested in the future given the large decreases in emissions that have occurred over the last decade.

[35] National Research Council Study, *Hidden Costs of Energy*, pp. 91.

[36] Ibid, pp. 88.

2.3.6 Unit Damage Costs – CO_2

For our CO_2 damage costs inputs, we used the latest social cost of carbon estimates developed by the federal government's Interagency Working Group on Social Cost of Carbon in 2013.[37] These values are used by federal government agencies for their regulatory analyses. The social cost of carbon estimate is "intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change."

Three social cost of carbon estimates are provided based on 2.5, 3 and 5 percent discount rates, using the average results from three models and five socioeconomic scenarios. A fourth carbon cost estimate is the 95^{th} percentile of the estimates using a 3 percent discount rate and is intended to represent higher than expected economic impacts. The average results using the 3 percent discount rate is "the central value," but the Interagency Group "emphasizes the importance and value of including all four [carbon cost] scenarios.[38] Including the 95^{th} percentile at a 3 percent discount rate is important because it highlights the variability in damage costs that exist within each discount rate scenario. As Table 2-7 shows, the damages in the 95^{th} percentile are nearly three times higher than the mean. The wide variation is due to uncertainty surrounding the extent of future gross domestic product (GDP) losses resulting from climate change. So, while it is clear that assumptions regarding discount rate have large impacts on the results of this analysis, it is important to realize that there is substantial uncertainty within each scenario that is not explicitly accounted for.

The table below presents the four Interagency Group carbon cost estimates in 1-year intervals starting in 2014. The weighted average estimated useful life of the ~~2012~~ 2013 EmPOWER program measures was ~~10~~ 12 years so we base our analysis on the average CO_2 values between 2014 and 2024.

[37] Interagency Working Group on Social Cost of Carbon. United States Government, Technical Support Document – Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866, May 2013.

[38] Interagency Working Group on Social Cost of Carbon. United States Government, Technical Support Document – Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866, May 2013, p.12.

Table 2-7: Social Cost of Carbon Dioxide ($2007 per Metric Ton)

Selected Years \ Discount Rates	5% Average	3% Average	2.5% Average	3% 95th Percentile
2014	11	37	57	106
2015	12	38	58	109
2016	12	39	60	113
2017	12	40	61	117
2018	12	41	62	121
2019	12	42	63	125
2020	12	43	65	129
2021	13	44	66	132
2022	13	45	67	135
2023	13	46	68	138
2024	14	47	69	141
Average 2014 thru 2024	**12**	**42**	**63**	**124**

Source: Interagency Working Group on Social Cost of Carbon. United States Government, *Technical Support Document – Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis* – Under Executive Order 12866, May 2013, p.18.

As noted above, between 2013 (the last year we adjusted for) and 2024 (the weighted average life of measures in the 2014 portfolio) , the share of coal is expected to go from 43% of total generation down to 39%, while gas is projected to increase from 24% to 27%.[39] These changes in fuel mix decrease the overall CO_2 emissions per kWh, and thus damage costs per kWh, by less than 1%. We multiply the EmPOWER program emissions reductions by 0.99 to reflect the projected reduction in CO_2 intensity resulting from fuel mix changes.

2.3.7 Carbon Taxes and Fees

As noted above, Maryland generators are subject to permit fees for EPA criteria emissions and must purchase allowances for carbon dioxide emissions as part of Maryland's participation in RGGI. Those fees are subtracted from the externality damage cost estimates in our analysis. As discussed in previous sections, the criteria permit fees add up to only a few thousandths of a cent per kWh in Maryland. Consequently, they have no impact on our benefits estimates.

Utility spending for RGGI allowances are significant, however. We adjusted CO_2 damages costs to reflect the effective carbon price created by the RGGI allowance auctions. The presumption is that the RGGI allowance prices are counted in utility avoided generation cost forecasts. If we did not reduce the allowance purchases from the benefits, we would in effect be double counting

[39] Source: Data from Energy information Administration, *Annual Energy Outlook 2014*, Table A8.

them – i.e., they would be included in the avoided supply costs and in the externality damage costs.

We made several adjustments to historical RGGI allowance auction prices. Table 2-8 shows RGGI auction clearing prices before and since the new RGGI rules (discussed on p. 2-6) were instituted. The new rules will lower the RGGI emissions caps and, all else equal, would be expected to increase allowance prices.

We also adjusted for allowance set asides. Set asides are distributed to states, which can distribute them to emitters at their discretion. States may offer the set asides to particular entities at no or low cost, or as credits for CO_2 reductions achieved between 2006 and 2008. About six percent of total allowances distributed to date by RGGI as a whole have been set asides.[40] However, in past years at least some states have simply retired many of these set aside allowances, rather than sell or give them away.

Based on perusal of RGGI auction results, it appears that only 1.8 million of Maryland's allowances have actually been distributed outside auctions, compared to 143 million allowances than have been auctioned. Even assuming that all of Maryland's distributed set aside allowances were given for free, the effective per ton CO_2 price to date would still be nearly 99 percent of the auction clearing price. The average allowance price assuming all Maryland set asides that were distributed were given away for free in reported in the last column of the table.

[40] RGGGI, 2013 Annual Report, p.14. RGGI also offers allowance offsets for CO2 reductions achieved through CO2 reduction or sequestration projects occurring outside the capped electric generation sector, but no offsets have been awarded to date.

Table 2-8: Comparison of Auction Results Before and After the New Model Rule Announcement

Auction #	Auction Allowances	Auction Proceeds ($)	Auction Clearing Price ($)	Auction Date	Average Price incl Set Asides
Auction 19	9,579,963	26,823,896	$2.86	13-Mar	$2.83
Auction 20	9,579,963	30,751,681	$3.28	13-Jun	$3.25
Auction 21	8,739,921	23,335,589	$2.73	13-Sep	$2.70
Auction 22	8,739,920	26,219,760	$3.06	13-Dec	$3.03
Auction 23	4,842,487	19,369,948	$4.00	14-Mar	$3.96
Auction 24	3,725,941	18,704,224	$5.02	14-Jun	$4.97
Since New Rule (Auctions 19-24)	45,208,195	145,205,097	$3.26	Mar-13 thru Jun-14	$3.23
Pre New Rule	97,522,982	219,115,649	$2.25	Sep-08 thru Dec-12	$2.22
All Auctions	142,731,177	364,320,747	$2.55	Sep-08 thru Jun-14	$2.53

Sources: Data compiled and/or calculated from the following RGGI website reports: http://www.rggi.org/docs/Auctions/24/MD_Procceds_By_Auction.pdf; and http://www.rggi.org/market/co2_auctions/results.

At least two conceptual challenges emerged in estimating an effective RGGI carbon price to be subtracted from the CO_2 damage cost.

First, auction clearing prices have varied significantly and recent changes in RGGI program have led to significant auction price increases since the end of 2012. As shown in the table below, since the inception of RGGI in 2008, auction clearing prices for Maryland allowances averaged $2.55 per ton. However, the Maryland clearing prices since the new model rule was announced have averaged $3.26 per ton and the latest auction cleared at $5.02 per ton.

A second uncertainty is the large number of surplus allowance holdings. According to RGGI, there were 140 million surplus allowances as of the end of 2013.[41] Over half of those surplus allowances are in the hands of investors. Some of these "banked" allowances could turn out to have been overvalued by auction buyers if actual emissions do not increase significantly above future caps or new rules requiring that banked allowances be used.

41 RGGI, 2013 Annual Report, pp. 8 and 33. As of December 31, 2013, 319 million allowances were in circulation with only 179 million needed to cover cumulative emissions. More than half of the surplus allowances were held by investors.

Ultimately, allowance values will be determined by a combination of economic, demographic, and regulatory decisions that are difficult to predict. EPA carbon regulations could reduce actual emissions and, unless RGGI caps are lowered, the need for RGGI allowances. The EPA regulations would then lower RGGI allowance values. In the extreme and unlikely event that Maryland followed New Jersey and withdrew from RGGI, the Maryland surplus allowances could be worth nothing.[42] On the other hand, a major economic boom, growing population or higher than anticipated cost of emissions control, could cause actual emissions to be greater than anticipated by investors, thus making the actual value of the allowances greater than the average auction clearing price.

For our base case, we used the average auction clearing price since the new rule of $3.26 per ton, which, when applied to 99 percent of emissions gives a CO_2 price of $3.23 per ton. Ideally, the RGGI allowance price assumption used to adjust damage costs should be equal to the allowance price assumption used by utilities for their avoided costs forecasts. But we do not know what future allowance prices will be, or more specifically, the prices that will be assumed in utility avoided costs forecasts. The average clearing price in the latest auction – as shown in Table 2-8, the March 2014 auction clearing price was $5.02 per ton, which applied to 99% of emission would equal $4.97. At least one RGGI study projected that allowance prices would reach $10 by 2020. A low end estimate of the RGGI carbon price might be based on the auction reserve price of $1.93 per ton applied to 99% of emissions, which would equate to a CO_2 price of $1.91 per ton.

Final Carbon Price

The table below shows adjustments we made to the Interagency Working Group carbon price estimates. Adjustments included 1) converting from 2010 to 2013 prices, and 2) subtracting RGGI allowance prices.

Table 2-9: Adjustments to Federal Regulatory Carbon Prices

Interagency Task Force CO_2 Damage Costs per Ton ($2010)			Adjusted CO_2 Damage Cost per Ton ($2013)			RGGI Allowance Price per Ton ($2013)	Net (minus RGGI allowance price) CO_2 Damage Cost per Ton ($2013)		
@5%	@3%	@2.5%	@5%	@3%	@2.5%		@5%	@3%	@2.5%
12	42	63	14.19	48.19	72.60	$3.26	10.92	44.93	69.34

[42] New Jersey withdrew from RGGI in 2011. RGGI 2013 Annual Report, p.12.

2.3.8 Costs of Compliance with Existing Regulations

Some Cost Effectiveness Working Group members expressed concern that we could be double counting emission control costs. Existing emission control costs and fees are presumably included in utility avoided costs projections. Even some future compliance costs could be included in avoided cost projections to the extent that these forward costs are anticipated and included, for example, in PJM Reliability Pricing Model auction bid prices.

Our analysis does not double count emissions control costs. There is no overlap between reduced air emissions damages and already curtailed emissions – damage costs arise from emissions that have not been curtailed.

As discussed above, there is, overlap between emissions externality costs and emissions that are subject to fees, such as the Regional Greenhouse Gas permits and the criteria air emission permits. Those fees are subtracted from the externality damage cost estimates in our analysis. If the fees were not subtracted, the emission permit value would be double counted – i.e., included in the avoided supply costs and in the externality damage costs.

2.3.9 Emissions Scope

Approximately 70% of the ozone measured in Maryland originates in NOx emissions from upwind states. PJM electricity coming into Maryland could be generated as far away as Illinois. It is consequently unclear the extent to which a kWh reduction from EMPOWER programs will impact in-state emissions or emissions concentrations.

Estimating the air emissions benefits specific to Maryland residents is beyond the scope of this analysis. Analysis of criteria emissions benefits would require development of Maryland concentration response functions and analysis of air emissions transport into and out of the State. While challenging, this analysis at least is conceptually grounded in existing models, such as those used for the Hidden Costs study. Therefore, developing reasonably accurate estimates of the benefits to Maryland residents of EmPOWER induced reductions in criteria emissions is probably feasible, though it would require significant investment.

Whether such an effort would be worthwhile is another question. Even in the aggressive case, our analysis concludes the sum of criteria emissions benefits totals less than one cent per kWh saved, which is unlikely to materially affect EmPOWER cost effectiveness either at the program or portfolio levels – i.e., only rarely, will a TRC B/C ratio go from less than one to greater than one if given additional benefits of 0.8 cents per kWh.

It is not clear what even the conceptual basis for allocating the impacts of CO_2 reductions to Maryland residents would be. CO_2 emissions originating in Maryland and the PJM will flow into the global stock of atmospheric CO_2. Maryland residents will be affected as much by a ton of

CO_2 emitted in Asia as in Maryland. The Interagency Working Group on Social Cost of Carbon acknowledged this issue and chose to count global damages from a ton of carbon.

Cost Effectiveness Working group members offered several opinions on the question of allocation of criteria emissions and CO_2 to Maryland residents. Some members felt this was an additional point of major uncertainty that further undermines any attempt to estimate and apply an air emissions benefit to the EmPOWER program cost effectiveness. This argument does not get around the fact that emissions benefits are not zero and that a well vetted, though still highly uncertain, non-zero value could be more accurate than the currently assumed benefit of zero.

At the other end of the spectrum, some members of the Cost Effectiveness Working Group insist that all emissions should be counted. If the emissions are the result of Maryland electric consumption, whether they affect children and elderly in Maryland or Ohio or North Carolina is not important. Maryland residents (more specifically, ratepayers) may not be as willing to pay higher electricity prices to benefit people in other states, especially when other states, have long ignored Maryland pleas to reduce emissions.

Some members argued that to the extent Maryland is seen as leading by example on criteria air emissions, other upwind states could be more inclined to follow. The Healthy Air Act demonstrates Maryland's willingness to take early action on criteria pollutants. Maryland's participation in RGGI, along with a range of other climate related policies including EmPOWER, demonstrates the State's willingness to take early action on CO_2. The lead by example argument is challenged by the fact that other states emissions continue to come into Maryland despite Maryland already having some of the most stringent emissions regulations in the country. Moreover, without national and global cooperation on CO_2 emissions, investments in reducing Maryland's CO_2 emissions will be largely for naught.

Ultimately, we were unable to find agreement on the appropriate allocation of EmPOWER emissions reduction to Maryland residents. As discussed below, we applied three different percentage allocations: 10%, 50% and 100%.

2.4 Results

We estimated benefits associated with three different scenarios. These scenarios at least roughly correspond with the cases proposed by the Cost Effectiveness Working Group for the EmPOWER Potential Study.[43] The emissions benefits are provided on a discounted cents per kilowatt-hour basis and should be applied to all EmPOWER kWh savings over the lives of the

[43] Alternative scenarios may be produced upon request from the Working Group.

program measures.[44] They could be applied alone or in conjunction with other non-energy benefits.

The first scenario corresponds with the Working Groups mid-case scenario and represents our best estimate of the air emissions benefits per kWh saved by the EmPOWER programs. It is based on a 3 percent real discount rate, assumes a CO_2 damage cost of $45/ton (after RGGI allowances), and counts only 50% of CO_2 and criteria emissions.

Under this scenario, the estimated present value benefit from reduced air emissions from the EmPOWER programs would total $~~44.1~~ 79 million over the lives of the program measures. This is equal to 1.~~05~~ 1 cent~~s~~ per kWh saved by the EmPOWER programs in ~~2012~~2013. Counting air emissions benefits would have increased the statewide TRC B/C ratio to 2.~~05~~1, a ~~14~~ 16 percent increase over the preliminary B/C ratio ~~over the B/C~~ of 1.8 without air emissions benefits; program level B/C ratios would increase by the same percentage.

Table 2-10: EmPOWER Air Emissions Benefits: Enhanced Scenario

	Emissions Reductions	PV Measure Life ($)	PV Cents per kWh Saved	% Change to 2012 TRC
CO_2 (metric tons)	1,866,774 ~~1,050,086~~	50,211,684 ~~28,001,211~~	0.67 ~~0.67~~	10%~~9%~~
NOx (lbs)	1,696 ~~954~~	1,927,884 ~~1,099,517~~	0.03 ~~0.03~~	1%~~0%~~
SO_2 (lbs)	3,874 ~~2,179~~	26,672,648 ~~15,043,148~~	0.36 ~~0.36~~	6%~~5%~~
Total	NA ~~NA~~	78,812,216 ~~44,143,876~~	1.06 ~~1.05~~	16%~~14%~~
Assumptions:	*Real Discount Rate*		3.0%	
	CO_2 Price		$45	
	% Emissions Counted		50%	

The second scenario corresponds with the business as usual case of the Working Group. It is based on a 5 percent real discount rate, assumes a CO_2 damage cost of $11/ton, and counts only 10% of CO_2 and criteria emissions.

Under this scenario, the estimated present value benefit from reduced air emissions from the EmPOWER programs would total $~~4~~7.5~~.3~~ million over the lives of the program measures. This

44 If measure savings shares vary widely over time, a more accurate valuation would estimate and discount annual benefits at the measure level.

is equal to 0.1 cents per kWh saved by the EmPOWER programs in ~~2012~~2013. Counting air emissions benefits would have no material impact on the statewide or program TRC B/C ratios.

Table 2-11: EmPOWER Air Emissions Benefits: Business as Usual

	Emissions Reductions	PV Measure Life ($)	PV Cents per kWh Saved	% Change to 2012 TRC
CO_2 (metric tons)	373,355 ~~210,017~~	2,463,068 ~~1,361,634~~	0.03 ~~0.03~~	1%~~0%~~
NOx (lbs)	339 ~~191~~	340,842 ~~196,675~~	0.00 ~~0.00~~	0%~~0%~~
SO_2 (lbs)	775 ~~436~~	4,715,621 ~~2,696,246~~	0.06 ~~0.06~~	1%~~1%~~
Total	NA ~~NA~~	7,519,531 ~~4,254,555~~	0.10 ~~0.10~~	2%~~1%~~
Assumptions:	*Real Discount Rate*		5.0%	
	CO_2 Price		$11	
	% Emissions Counted		10%	

The third scenario corresponds with the aggressive case of the Working Group. It is based on a 2.5 percent real discount rate, assumes a CO_2 damage cost of $69/ton, and counts all CO_2 and criteria emissions.

Under this scenario, the estimated present value benefit from reduced air emissions from the EmPOWER programs would total $~~120~~ 212 million over the lives of the program measures. This is equal to 2.9 cents per kWh saved by the EmPOWER programs in ~~2012~~2013. Counting air emissions benefits would have increased the statewide TRC B/C ratio to 2.~~5~~6, a ~~38~~ 44 percent increase over the preliminary B/C ratio of 1.8 without air emissions benefits; program level B/C ratios would increase by the same percentage.

Table 2-12: EmPOWER Air Emissions Benefits: Aggressive

	Emissions Reductions	PV Measure Life ($)	PV Cents per kWh Saved	% Change to 2012 TRC
CO_2 (metric tons)	3,733,549 ~~2,100,173~~	153,901,459 ~~86,426,789~~	2.06 ~~2.06~~	32%~~27%~~
NOx (lbs)	3,392 ~~1,908~~	3,981,164 ~~2,264,805~~	0.05 ~~0.05~~	1%~~1%~~
SO_2 (lbs)	7,747 ~~4,358~~	55,080,189 ~~30,971,937~~	0.74 ~~0.74~~	11%~~10%~~
Total	NA ~~NA~~	212,962,812 ~~119,663,531~~	2.86 ~~2.85~~	44%~~38%~~
Assumptions:	*Real Discount Rate*		2.5%	

	CO_2 Price	$69
	% Emissions Counted	100%

2.5 Recommended Values and ~~Appropriate Benefit~~ Benefit-Cost Test

Significant Working Group discussion revolved around whether environmental externality benefits of the EmPOWER programs should be included in the Total Resource Cost Test (TRC), which is the primary test considered by the Commission, or only in the Societal Cost Test (SCT).

There are no clear rules for or against inclusion of environmental externalities in a TRC and no clear standard practice. According to ACEEE in a 2012 report, fourteen States include externality benefits in their primary benefit cost test. The SCT is the primary test in six states, while the TRC is the primary test in 29 states. That suggests that at least 8 states (14 minus 6) include externality costs in their TRC.

The Maryland Assembly, in crafting the EmPOWER ACT, clearly stated reducing the environmental impacts of electricity as an objective. If environmental benefits are a primary objective of the EmPOWER mandates and the Commission accepts that there could be costs associated with environmental improvement, it may want to incorporate them into the TRC test, which, at least to date, has been the primary test used to assess portfolio and program performance.

The EmPOWER Act distinguishes between impact on the environment and cost effectiveness, however, and at least seems to suggest that cost effectiveness should be looked at separately from environmental benefits:[45]

> *In determining whether a program or service encourages and promotes the efficient use and conservation of energy, the commission shall consider the: (i) cost–effectiveness; (ii) impact on rates of each ratepayer class; (iii) impact on jobs; and (iv) impact on the environment.*

This framing actually is congruent with arguments made by energy efficiency program advocates that energy efficiency can provide societal benefits at a "negative" cost -- i.e., that a reduction in energy consumption through improved efficiency can be procured at lower cost than the lowest cost supply resource, that even without formally considering the environmental benefits, the programs are cost effective.

45 House Bill 374, Section 1 (A) (1).

If the intent of the Maryland Assembly was to achieve environmental benefits from energy efficiency improvements at zero or negative cost, then it could make sense to consider environmental externality costs separately from the primary TRC analysis in a separate societal or enhanced TRC benefit-cost analysis.

A notable concern about this path is that it could effectively ascribe a value of zero to the environmental damages benefits resulting from the EmPOWER programs. A 1.115 cent/kWh environmental adder was included in the Societal Cost Test (SCT) of the ex ante analysis used for the 2009-11 and 2012-14 EmPOWER program plans for four of the five of the EmPOWER utilities (PE did not include it). Aside from this adder, there has been no attempt to include environmental externality costs into the EmPOWER ex ante or ex post cost effectiveness analyses. To date, the ex post cost effectiveness analyses have not included an SCT and the ex ante SCT was not a consideration in the development and review of the previous three-year plans.

We recommend that future ex ante and ex post cost effectiveness analyses for all EmPOWER programs include a 1.1 cents ($ 2014) per kWh adder. A price inflation escalator should be applied for each year of the measure life. These values should be multiplied by the kWh saved in each year for the life of each measure to calculate the annual nominal air emissions benefits. These benefits should be multiplied by the NTG ratio for each measure or program and discounted like other benefits.

3

Comfort

3.1 Introduction

Comfort is one of the most commonly cited NEIs and is an especially important benefit for programs that include residential air sealing and insulation (i.e., shell measures). In this chapter, we apply comfort benefits used for comparable Massachusetts energy efficiency programs to two EmPOWER residential programs -- Home Performance with Energy Star (HPwES) and Limited Income. The Massachusetts comfort benefits are adapted to more closely reflect the Maryland programs' measure mix, in particular shell measures.

Comfort benefits are hard to quantify and monetize as they cannot be measured directly, and significant uncertainties exist around their estimated or self-reported dollar values. Four states in the Northeast MA, RI, DC and VT) include comfort benefits in their cost effectiveness tests.[1] California and New York only allow health, safety, and comfort impacts into the cost-effectiveness screenings for low-income programs. MA and NY have estimated comfort impacts as part of dedicated studies. CA and RI rely on secondary sources (e.g., the RI TRM uses MA estimates). Some other states (IA, CO, OR, WA, VT, DC, ID, UT, WY) include generic NEI adders of which comfort impacts may be implicitly or explicitly included. [2]

Importantly, our analysis is limited to comfort benefits, but the Massachusetts study examines a broad set of non energy impacts in Massachusetts. These other benefits should be considered for inclusion in future EmPOWER cost effectiveness analyses.

3.2 Our Methods and Assumptions

The basis for our calculations is per participant household benefits provided in a study conducted for Massachusetts[3] program administrators, conducted by Tetra Tech and Nexus Market

[1] Tim Woolf, Eric Malone, Jenn Kallay, and Kenji Takahashi, Energy Efficiency Cost-Effectiveness Screening in the Northeast and Mid-Atlantic States, Synapse Energy Economics, prepared for the Regional EM&V Forum, October 2, 2013, p.9.

[2] Skumatz, Lisa. "Non-Energy Impacts / Non-Energy Impacts and Their Role and Values in Cost Effectiveness Tests, State Of Maryland" SERA Inc. March 2014.

[3] Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Tetra Tech and Nexus Market Research. August 2011.

Research, which quantified health and comfort NEIs by surveying program participants. This study surveyed 209 energy efficiency program participants and another 213 low-income program participants using a direct query method which asks participants to value impacts relative to the average bill savings for participants in the program.

The Massachusetts study estimated NEIs for specific measures, which allows us to apply them to the EmPOWER HPwES and Limited Income program measure mix. Specifically, the Massachusetts comfort benefits were ascribed to participants that made shell and/or HVAC improvements. This mapping of measures to savings was not found in any of the other studies we reviewed.

Ultimately, our decision to base our EmPOWER comfort benefits estimates on the Massachusetts study hinged on the following factors:

- It describes a plausible hypothesis for what causes non-energy impacts and thus creates monetary value to participants.
- It accounts for interactive effects between measures and makes adjustments to avoid double counting of benefits.
- It entertains the possibility that there may be costs, rather than benefits, related to the installation of energy efficiency measures.
- The sample was deemed to be robust, unbiased, and well designed.
- The study is relatively recent (2011).
- The study was performed by experienced third party consultants who are not advocates or affiliated with any advocacy groups.
- The study was reviewed by utility clients and their stakeholders before final publication.

Applying the Massachusetts comfort benefit estimates to the EmPOWER programs was straight forward. The calculations and assumptions for the HPwES programs are summarized in Table 3-1 and Table 3-2. We first converted the Massachusetts per participant benefits to 2014 dollars using the Consumer Price Index. We then multiplied the annual per participant benefit by the TRM-prescribed EUL for air sealing to arrive at the lifetime benefit per participant. The present value of the lifetime benefit was then calculated using a 5% real discount rate. As shown in Table 3-1, the estimated average PV lifetime benefit per participant installing shell measures for the HPwES program is $1,416.

Table 3-1: Comfort Benefits per Participant – HPwES

	Annual Gross Benefit per Participant MA HH (2010 $)	Annual Benefit per MA Participant HH (2014 $)	TRM-Prescribed Air Sealing EUL	Lifetime Benefit per MA Participant HH (2014 $)	PV (5%) Lifetime Benefit per MA Participant HH (2014 $)
Statewide	125	136	15.00	2,046	1,416

To show the magnitude of the impacts, for each EmPOWER utility, we then multiplied by the number of 2012 EmPOWER HPwES program shell participants and the 2012 EmPOWER HPwES NTG ratio. The final result is the estimated 2012 EmPOWER HPwES PV comfort benefits in 2014 dollars. The assumptions and sources for these various data are presented in Table 3-2 and include the 2012 EmPOWER evaluation and cost effectiveness studies and the Massachusetts study.

As shown, the statewide HPwES comfort benefits totaled $2.9 million and ranged from more than $1.9 million (PEPCO) to less than twelve thousand dollars for PE, which reported only a handful of shell participants.

Table 3-2: 2012 Comfort Benefits -- HPwES

	PV Lifetime Benefit per MA Participant HH (2014 $)	2012 EmPOWER HH Participants	2012 EmPOWER Shell Participants (%)	2012 EmPOWER NTGR	2012 EmPOWER PV Comfort Benefit (2014 $)
Statewide	1,416	**4,798**	**65%**	**0.66**	**2,917,798**
BGE		1,765	43%	0.66	713,315
PEPCO		2,329	90%	0.66	1,949,291
DPL		163	69%	0.66	105,426
SMECO		178	87%	0.63	138,255
PE		363	3%	0.69	11,511
Sources	Calc	Navigant 2012	Cadmus 2012	Navigant 2012	Calc

The calculations and assumptions for the limited income programs are summarized in Table 3-3 and Table 3-4. They are nearly identical to those of the HPwES program. The only major differences are that the Massachusetts per participant comfort benefit is lower, and the calculations are based on 2011 program activity rather than 2012 program activity. The limited income program evaluations have not been verified by Itron and Commission Staff since the 2011 program year, so it is the most recent data available.

As shown in Table 3-3, the estimated average PV lifetime benefit per participant installing shell measures for the limited income program is $1,144.

Table 3-3: Comfort Benefits per Participant – Limited Income

Limited Income	Annual Gross Benefit per MA Participant HH (2010 $)	Annual Benefit per MA Participant HH (2014 $)	TRM Prescribed Air Sealing EUL	Lifetime Benefit per MA Participant HH (2014 $)	PV (5%) Lifetime Benefit per MA Participant HH (2014 $)
Statewide	101	110	15.00	1,653	1,144

As shown in the Table 3-4, the statewide limited income program comfort benefits totaled just over $2.6 million and ranged from nearly $1.6 million (BGE) down to a little over one hundred thousand dollars for SMECO.

Table 3-4: 2011 Comfort Benefits per Participant – Limited Income

	Lifetime Benefit per MA Participant HH (2014 $)	2011 EmPOWER HH Participants	2012 EmPOWER Shell Participants (%)	2011 EmPOWER NTGR	2011 EmPOWER PV Comfort Benefit (2014 $)
Statewide	1,144	**3,550**	**64%**	**1.00**	**2,615,527**
BGE		1,868	74%	1.00	1,581,021
PEPCO		244	46%	1.00	128,374
DPL		179	52%	1.00	106,460
SMECO		110	82%	1.00	103,166
PE		1,149	53%	1.00	696,506
Sources	Calc	Navigant 2011	Navigant 2011	Navigant 2011	Calc

3.2.1 Uncertainties

While we are reasonably confident that the methods used here and in the underlying Massachusetts study accurately reflect the value placed on comfort by HPwES and limited income participants, there at least several significant sources of uncertainty with our analysis of EmPOWER comfort benefits as summarized below.

Self Report Methods

The Massachusetts study is based on self-reported benefits from program participants. Self-report surveys that ask participants to value NEIs are often the subject of controversy due to the inherent biases that participants may have. The accuracy of the self-report method depends on respondents providing candid and knowledgeable responses. Without revealed preference methods, however, self-report surveys are the only way to assess participant NEI values despite their biases.

<u>Data Quality</u>

Since comfort benefits have not been considered in the EMPOWER evaluations or cost effectiveness analyses to date, we had to cobble data pertaining to participation, shell and HVAC measures from a variety of sources. The quality of the various data can be vastly improved if it is collected and reported as part of the other evaluation and cost effectiveness data requests. If the comfort benefit is used in future ex ante and/or ex post cost effectiveness analysis, as we recommend, Itron will provide clear guidance to utilities and contractors about the data that is needed.

<u>Application of Massachusetts Study Benefits to Residential HVAC</u>

The MA study estimated participant household comfort benefits for shell improvements, HVAC improvements, and shell and HVAC improvements combined. We applied the MA Study per participant benefit to all HPwES and limited income participants that implemented shell measures. We did not apply the comfort benefit to the residential HVAC program.

The EmPOWER residential HVAC evaluation generally assumes that new efficient HVAC systems are purchased in lieu of alternative standard efficiency units (e.g., SEER 13 central air conditioners); the incentives provided by the programs are not considered sufficient to drive replacement of HVAC systems with any significant remaining life. While Massachusetts HVAC program respondents reported comfort benefits, we are unclear how a new energy efficient HVAC unit would provide significantly greater “comfort” than a new standard efficiency unit. We suspect that MA survey respondents could have been comparing the comfort of their new efficient units to the units that were replaced.

It is also possible that the Massachusetts survey respondents were ascribing greater comfort to the efficient unit because the lower operating costs will allow them to run the unit more frequently or at different set temperatures (i.e., there is a rebound effect). If so, the comfort benefit would be at least partially offset by increased energy consumption and lower energy savings benefits for the program. If the program impact evaluation included pre/post or billing data analysis, then the energy savings (or lack thereof) would have been accounted for and then comfort benefits should be included. The EMPOWER residential HVAC program evaluation has never included a bill analysis, however. To the extent that a rebound effect is occurring, the evaluated energy savings are likely overstated and hence comfort benefits should not be included.

3.3 Results and Application

In this section we summarize the results of our analysis and provide recommendations for their application to the EmPOWER ex ante and ex post cost effectiveness analyses.

We recommend that Massachusetts comfort benefits of $136 and $110 should be applied, respectively, for every HPwES and limited income participant for which air sealing and/or insulation measures are installed as a result of the program (i.e., after adjusting for free ridership and spillover). The values should be applied annually for 15 years. These values are in 2014 dollars and should be escalated by the inflation rate used in the analysis.

These benefits should be added to other discounted electric and non-electric benefits in the TRC and SCT (and the participant cost test if it is estimated for future EMPOWER program cycles). For the MEA potential study, we offer a straw man propose that 25% of the values be applied for the low case and 150% of the value be applied to the high case, but must point out that these adjustment percentages are arbitrarily selected and we would defer to the MEA Cost Effectiveness Working Group on these ranges.

Table 3-5 and Table 3-6 below report the impacts on the TRC benefit cost ratios if the recommended comfort benefits had been included in the 2012 HPwES and the 2011 limited income program cost effectiveness analyses.

As shown in Table 3-5, the comfort benefits would have increased the statewide TRC B/C ratio for the HPwES programs from 0.6 to 0.79. While a significant boost to the programs, it would not in itself have made any of the utilities programs cost effective. The PEPCO TRC would have received the greatest boost from including the comfort benefit and would have come close to passing the TRC.

Table 3-5: Comfort Benefits Impact on EmPOWER HPwES Program Cost Effectiveness

	2012 PV Comfort Benefit (2014 $)	2012 TRC PV Benefits (2014 $)	2012 TRC B/C Ratio	Rev 2012 TRC BC Ratio	2012 Net Lifetime MWH Savings	2012 PV Comfort Benefit Cents per Net kWh Saved
Statewide	**2,917,798**	**9,117,856**	**0.6**	**0.79**	**55,335**	**5.27**
BGE	713,315	4,510,180	0.7	0.81	24,960	2.86
PEPCO	1,949,291	3,713,344	0.59	0.90	22,740	8.57
DPL	105,426	443,091	0.46	0.57	2,745	3.84
SMECO	138,255	356,046	0.52	0.72	1,800	7.68
PE	11,511	95,197	0.11	0.12	3,090	0.37

As shown in Table 3-6, the comfort benefits would have increased the statewide TRC B/C ratio for the limited programs from 0.55 to 0.69. As with the HPwES programs, the comfort benefit would significantly increase the limited income program TRC B/C results, but it would not in itself have made any of the utilities programs cost effective. The PE TRC would have doubled. For both BGE and PE, the TRCs would have come much closer to passing the TRC.

Table 3-6: Comfort Benefits Impact on EmPOWER Limited Income Program Cost Effectiveness

	2011 PV Comfort Benefit (2014 $)	2011 TRC PV Benefits (2014 $)	2011 TRC BC	Rev 2011 TRC BC	2011 Net Lifetime MWH Savings	2011 PV Comfort Benefit Cents per Net kWh Saved
Statewide	**2,615,527**	**10,212,779**	**0.55**	**0.69**	**831,810**	**0.31**
BGE	1,581,021	6,664,950	0.65	0.80	730,425	0.22
PEPCO	128,374	902,160	0.36	0.41	28,665	0.45
DPL	106,460	1,448,212	0.60	0.64	4,320	2.46
SMECO	103,166	513,195	0.30	0.36	50,055	0.21
PE	696,506	684,262	0.38	0.77	18,345	3.80

4

O&M Benefits from EmPOWER Commercial & Industrial Programs

4.1 Introduction

In this chapter, we examine the magnitude and potential methods for estimating operation and maintenance (O&M) benefits resulting from investments promoted by the EmPOWER Commercial and Industrial (C&I) Prescriptive and Small Business Direct Install (SBDI) programs. We provide a bottom-up engineering estimation of the O&M benefits associated with occupancy sensors and lamp replacements, which are the single largest source of O&M benefits for these programs based on the analysis presented here. Data limitations precluded estimation of some other O&M benefits and we chose not to use other O&M benefits from HVAC and Variable Frequency Drive (VFD) measures that are commonly cited in the literature; these issues are discussed below. The lighting measures included in our benefit estimates comprise 71 percent and 77 percent, respectively, of the total Prescriptive and SBDI kWh savings and similarly large shares of measure unit quantities.

Including the benefits from avoided C&I lamp replacement and occupancy sensor maintenance would give a modest boost to the cost effectiveness of the C&I programs.[1] Below, we describe our analytical methods and data, provide estimates of the O&M benefits from avoided lamp replacement, assess the impacts of including these benefits on 2013 TRC benefit cost ratios, and offer recommendations for how these estimates should be applied in future ex post and ex ante cost effectiveness analyses.

4.2 Methods and Data

At a high level, our analysis consisted of the following seven steps for each of the five utilities C&I programs:

1) Literature Survey
2) Identify priority measures
3) Establish conceptual basis for O&M benefits associated with the priority measures

[1] These benefits are not currently included in cost effectiveness analysis of commercial measures.

4) Develop algorithm for calculating the per-unit lamp replacement benefits
5) Estimate or source input parameter values
6) Calculate the measure-level benefits
7) Estimate impact of lamp replacement benefits on utility program-level TRC benefit cost estimates

Each of these steps is discussed below.

4.2.1 Literature Survey

The first step in our analysis was to identify key O&M benefits studies that could provide methodological insights or results that could be applicable to the EmPOWER programs. Few studies have rigorously attempted O&M benefits estimates at least in recent years. The Mid-Atlantic TRM prescribes lamp replacement benefits for the residential and C&I lighting measures.[2] Far and away the most comprehensive study we found was a Massachusetts Non-Energy Impacts study published in July 2012.[3] We reviewed other studies, but the TRM and Massachusetts studies were the only ones published in the last decade that contained original analysis (as opposed to summaries of other studies) and whose methods we thought might be sufficiently rigorous and transparent to be able to apply them to the EmPOWER programs.[4]

Upon further consideration, we determined that the O&M benefits estimates from these sources should not be used for the EmPOWER estimates because of a potential mismatch between baselines used by program participants to estimate energy and non-energy benefits. The methods and discussions in these studies did help inform our analysis and the Massachusetts study, in particular, could inform future broader based- studies of EmPOWER C&I O&M benefits.

Mid-Atlantic Technical Resource Manual

The Mid-Atlantic TRM prescribes lamp replacement cost savings values associated with residential and C&I lighting measures, which are based on engineering based calculations. The

[2] Northeast Energy Efficiency Partnership. Technical Reference Manual, Version 4.0, prepared by Shelter Analytics, June 2014. Other state and regional TRMs include lamp replacement cost benefits, but as a member of the Mid-Atlantic TRM Advisory Group, Itron had access to the background calculations.

[3] Tetra Tech, DNV GL, Final Report – Commercial and Industrial Non-Energy Impacts Study, prepared for the Massachusetts Program Administrators, June 29, 2012.

[4] Other studies we reviewed include: Roth, Johna and Nick Hall, *Non-Electric Benefits from the Custom Projects Program: A Look at the Effects of Custom Projects in Massachusetts*, TecMarket Works, prepared for: National Grid, September 25, 2007; Skumatz, Lisa A., Ph.D., Sami Khawaja, Jane Colby, *Lessons Learned and Next Steps in Energy Efficiency Measurement and Attribution: Energy Savings, Net to Gross, Non-Energy Benefits, and Persistence of Energy Efficiency Behavior*, Skumatz Economic Research Associates, prepared for California Institute for Energy and Environment (CIEE) Behavior and Energy Program, Berkeley, CA, November 2009; and Mosenthal, Phil and Matt Socks, *Non-Electric Benefits Analysis Update*, Optimal Energy, Inc., D.P.U. 09-119, Attachment AG-1-22 (j), November 7, 2008.

TRM does not include O&M benefits associated with occupancy sensors. The TRM is the default source for parameter inputs and algorithms in the EmPOWER impact evaluations and cost effectiveness analyses. The TRM is updated annually by NEEP with support from numerous advisory group members from states throughout the Mid-Atlantic region, including Maryland.

As the default document for the EMPOWER evaluations and cost effectiveness analyses, we considered using or adapting the prescribed values in the TRM to estimate lamp replacement benefits. However, in our review of the prescribed values, we identified some problems with the assumptions and calculations, which were confirmed in follow up discussions with the TRM authors.[5] While some of the methods were instructive, we ultimately determined to independently recalculate the lamp replacement cost savings.

Massachusetts Non-Energy Impact Study

The Massachusetts study is based on self report surveys of 1,499 program year 2010 prescriptive program participants and more than 258 custom program participants. It examined thirteen NEI types across six major measure types. The large study sample enabled the authors to develop statistically significant estimates for many of those measure categories and NEIs for both custom and prescriptive programs, as presented in the tables below.[6]

Table 4-1: Massachusetts Study Gross Annual Non-Energy Impacts per kWh – Prescriptive Electric

NEI Reporting Category	n	Average NEI	NEI/kWh	90% CI Low	90% CI High	% of Population kWh	Stat Sig
HVAC	27	$7,687	$0.0966	$0.0544	$0.1389	8%	Yes
Lighting	163	$1,636	$0.0274	$0.0176	$0.0372	69%	Yes
Motors and Drives	50	$541	$0.0043	($0.0005)	$0.0091	18%	No
Refrigeration	30	$5	$0.0013	($0.0002)	$0.0028	0%	No
Other	32	$28	$0.0039	($0.0002)	$0.0079	3%	No
Overall	**302**	**$1,439**	**$0.0274**	**$0.0188**	**$0.0360**	**100%**	**Yes**

[5] Itron will work with the TRM authors and Advisory Group to make necessary adjustments to these values as part of the 2015 (version 5) update).

[6] The Massachusetts study does not discuss the applicability of Prescriptive program results to SBDI programs.

Table 4-2: Massachusetts Distribution of Gross Annual Non-Energy Impacts by Category – Prescriptive Electric

NEI Reporting Category	Admin	Fees	Material Handling	Material Movement	Other Costs	Other Labor	O&M	Other Revenue	Product Spoilage	Rent Revenue	Sales Revenue	Waste Disposal	Total Impacts
HVAC	8.2%*	0.00%	0.00%	0.00%	3.40%	-0.30%	69.8%*	0.00%	0.00%	18.90%	0.00%	0.00%	100.0%*
Lighting	5.0%*	0.00%	2.9%*	0.40%	0.00%	7.30%	73.7%*	0.00%	0.00%	0.00%	8.30%	2.3%*	100.0%*
Motors and Drives	0.6%*	0.00%	0.0%*	0.0%*	4.90%	0.20%	94.80%	0.00%	0.00%	0.00%	-0.50%	0.0%*	100.00%
Refrigeration	0.0%*	0.00%	0.0%*	0.0%*	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.0%*	100.00%
Other	1.00%	0.00%	0.0%*	0.0%*	0.00%	0.00%	99.00%	0.00%	0.00%	0.00%	0.00%	0.0%*	100.00%
Overall	**5.4%***	**0.00%**	**2.4%***	**0.40%**	**0.60%**	**6.10%**	**73.5%***	**0.00%**	**0.00%**	**2.80%**	**6.90%**	**2.0%***	**100.0%***

Significance = *

Table 4-3: Massachusetts Study Gross Annual Non-Energy Impacts per kWh – Custom

NEI Reporting Category	n	Average NEI	NEI/kWh	90% CI Low	90% CI High	% of Population kWh	Stat Sig
CHP/Cogen	6	($12,949)	($0.0147)	($0.0247)	($0.0047)	11%	Yes
HVAC	20	$5,584	$0.0240	$0.0003	$0.0477	28%	Yes
Lighting	89	$5,686	$0.0594	$0.0318	$0.0871	25%	Yes
Motors and Drives	42	$1,433	$0.0152	($0.0005)	$0.0309	10%	No
Refrigeration	90	$1,611	$0.0474	$0.0244	$0.0705	8%	Yes
Other	29	$15,937	$0.0562	$0.0038	$0.1087	18%	Yes
Overall	**276**	**$4,454**	**$0.0368**	**$0.0231**	**$0.0506**	**100%**	**Yes**

Table 4-4: Massachusetts Distribution of Gross Annual Non-Energy Impacts by Category – Custom

NEI Reporting Category	Admin	Fees	Material Handling	Material Movement	Other Costs	Other Labor	O&M	Other Revenue	Product Spoilage	Rent Revenue	Sales Revenue	Waste Disposal	Total Impacts
CHP/Cogen	20.3%*	0.00%	0.00%	0.00%	0.00%	0.00%	79.7%*	0.00%	-0.0%*	0.00%	0.00%	-0.0%*	100.0%*
HVAC	6.10%	0.00%	0.00%	0.00%	9.60%	7.70%	70.80%	0.00%	2.00%	3.80%	0.00%	0.0%*	100.0%*
Lighting	5.2%*	0.00%	0.20%	0.40%	13.20%	0.0%*	79.7%*	0.00%	0.0%*	0.00%	0.1%*	1.2%*	100.0%*
Motors and Drives	1.40%	0.00%	0.00%	0.00%	0.00%	0.0%*	68.7%*	0.00%	29.90%	0.00%	0.00%	0.0%*	100.00%
Refrigeration	0.00%	0.00%	2.60%	0.00%	0.00%	0.0%*	55.8%*	0.00%	41.6%*	0.00%	0.00%	0.0%*	100.0%*
Other	0.00%	0.00%	0.00%	0.00%	0.00%	14.80%	-41.60%	0.00%	6.10%	0.00%	120.60%	0.10%	100.0%*
Overall	**2.40%**	**0.00%**	**0.40%**	**0.20%**	**7.60%**	**5.4%***	**40.80%**	**0.00%**	**7.8%***	**0.60%**	**34.30%**	**0.6%***	**100.0%***

Significance = *

We considered applying the results from the Massachusetts Non-Energy Impacts study to the EmPOWER programs, but ultimately decided not to use the MA study for several reasons. First, we were unable to get sufficiently granular information about individual lighting measures. Since 2010, the program year upon which the study is based, federal standards which prohibit the manufacture of most T12 lamps, have radically changed the lighting marketplace. The EmPOWER C&I lighting programs, like C&I programs in other states, are evolving in response to these new standards. Aside from CFLs, there are three major measure types:

1) Replacing T12s with standard T8s,
2) Replacing standard T8s with high performance T8s, and
3) Replacing fluorescent lamps with LED lamps.

Replacing standard T8s with high performance T8s will provide a much smaller O&M benefit than replacing T12s with T8s because the differences between measure and baseline EULs are smaller. Replacing fluorescents with LEDs will provide a much larger benefit. To the extent that Massachusetts program participants surveyed in 2010 were referring to early replacement of replacement of older T12 systems, their estimated O&M benefits would be too high to apply to current and future programs. Without knowing the individual lighting measures in the 2010 MA portfolio or more precisely the types of lighting configurations that the survey respondent were referencing, we had no way to adjust the Massachusetts study O&M estimates to reflect the EmPOWER program measure mix.

Second, we were unclear about what was driving the MA Study results for some of the measure benefits. For example, as shown in

Table 4-4 above, the custom program "Other" measure category "O&M" benefit was highly negative while "Sales Revenues" were highly positive. We suspected, but were unable to verify, that this project involved expanded production; we cannot otherwise see how this measure would offer such a high additional O&M costs and additional sales revenue.[7] If the project involved expanded production, however, the baseline for comparison should be the standard efficiency equipment that would have been purchased, not the *in situ* condition in which there was no expanded production.

Another measure benefit that gave us pause was the prescriptive program HVAC, which was nearly 10 cents per kWh. We suspected this high value was driven by survey respondents comparing their *in situ* units to the new efficient units, rather than comparing a new standard efficiency to the new high efficiency model. Our review of the survey O&M battery found no clear guidance for respondents to compare to the equipment they purchased to the equipment they would have purchased if not for the program incentive. And the formulas that were reportedly used to estimate the benefits associated with these measures compares the new systems to the old *in situ* systems, rather than the systems that would have been purchased.[8]

If the replacement of the *in situ* HVAC units was induced by the program, then the comparisons between the in situ and new efficient units would be appropriate. But program incentives are typically set at levels that induce purchase of high efficiency units rather than standard units. The program incentive would have to be extremely large to induce replacement of an existing system that was not going to be replaced anyway. To be able to apply the MA study HVAC values to EmPOWER, we would need, at minimum, separate values for HVAC early replacements versus HVAC end of life replacements. This information was not available from the study authors. [9]

While we ultimately decided against using the Massachusetts study for our O&M benefits estimates, it employed best practice methods and could serve as a model for a more ambitious analysis of EmPOWER C&I non-energy impacts in the future.

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[7] In phone correspondence Massachusetts study lead author June 25, 2014, he said he could not say definitely what was causing the negative O&M nor the 120% "sales revenue" increase for the Custom "Other" measure category. He said they did everything they could to ensure no double counting – i.e., that the "increased sales revenue" benefit was net of cost of production. He also emphasized the study was intended to look at total NEIs and not the underlying NEI components.

[8] Tetra Tech, DNV GL, Final Report – Commercial and Industrial Non-Energy Impacts Study, prepared for the Massachusetts Program Administrators, June 29, 2012, Table 3-7, p. 3-23

[9] Phone correspondence Massachusetts study lead author June 25, 2014

4.2.2 Identify Priority Measures

We calculated kWh, kW and unit shares for all C&I Prescriptive and SBDI program measures to prioritize measure types. As shown in Table 4-5 and Table 4-6, lighting measures comprised the vast majority of kWh savings. Motors & VFDs were a distant second, driven by PEPCO and DPL. Other measures include refrigeration, building shell, and cooking measures.

Among the lighting measures, there were five major types: 1) linear fluorescent lighting, 2) interior LEDs, 3) exterior LEDs, 4) occupancy sensors, and 5) CFLs (SBDI only).[10] These measures, which are the measures we included in our O&M benefits estimates, comprise 71 percent of Prescriptive and 77 percent of SBDI kWh savings.

Table 4-5: 2013 Measure Percentage Shares of Total Reported Savings – Prescriptive

Utility	4 Major Lighting Measures*	Lighting	Motors & VFD	HVAC	Other	Total kWh
BGE	76%	82%	7%	1%	10%	88,318,086
PEPCO	56%	71%	19%	0%	11%	41,983,816
DPL	62%	86%	9%	0%	5%	9,538,556
SMECO	79%	82%	1%	1%	16%	4,356,341
PE	82%	84%	1%	0%	15%	18,769,096
Total	**71%**	**80%**	**9%**	**0%**	**11%**	**162,965,895**

* Includes linear fluorescent lighting, interior LEDs, exterior LEDs, and occupancy sensors.

Table 4-6: 2013 Measure Percentage Shares of Total Reported Savings – SBDI

Utility	5 Major Lighting Measures*	Lighting	Motors & VFD	HVAC	Other	Total
BGE	81%	91%	3%	3%	3%	37,186,106
PEPCO	79%	93%	0%	0%	7%	52,973,388
DPL	74%	91%	0%	0%	8%	14,852,340
SMECO	95%	100%	0%	0%	0%	1,549,704
PE	0%	12%	0%	0%	88%	2,202,276
Total	**77%**	**90%**	**1%**	**1%**	**8%**	**108,763,815**

* Includes CFLs, linear fluorescent lighting, interior LEDs, exterior LEDs, and occupancy sensors.

[10] Other lighting measures include exit signs, daylighting controls, and LED case lights.

4.2.3 Establish Conceptual Basis for O&M Benefits Associated with the Priority Measures

Based on our literature survey, we inventoried and assessed the potential significant sources of O&M benefits (and costs) associated with the priority lighting, HVAC and VFD measures. For various reasons discussed below, we concluded that the predominant O&M benefits for lighting are associated with avoided lamp replacement costs and avoided labor costs associated with switching off lights as a result of installing occupancy sensors.

As discussed below, we considered and ultimately decided against including O&M benefits associated with EMPOWER C&I program HVAC and VFD measures.

<u>Lighting</u>

Two major types of O&M benefits apply to lighting systems. First, costs associated with lamp replacement can be avoided as a result of installing high efficiency lighting systems. Specifically, LED lamps have longer lives than high efficiency T8s, which have longer lives than standard T8s, which have longer lives than T12s. The relative lamp replacement costs depend on the frequency of lamp replacement, the unit prices of the lamps, and the labor required to install them.

Second, occupancy sensors could provide additional lighting O&M benefit if building maintenance personnel avoid walking through buildings to switch lights on or off. We initially were reluctant to include these occupancy sensor maintenance cost benefits since the basis for energy savings from occupancy sensors is that maintenance staff do NOT spend time turning off lights. You can either claim energy savings or O&M savings, but to count both would be double dipping.[11] However, the Maryland evaluation and the Mid-Atlantic TRM only count 28% of energy and 14% of demand associated with the lighting systems attached to the sensors.[12] And those lighting systems energy and demand impacts are calculated using assumed business hours of use, which implicitly assumes that someone is turning off the lights outside of business hours.

We also were initially concerned about offsetting maintenance costs associated with occupancy sensors, for tuning and repairs that would not occur with a normal flip switch. While these offsetting costs do exist, we decided they were likely small compared to the daily labor costs associated with turning lights off at night.

[11] This view was also expressed by Bret Hamilton, Shelter Analytics, in email correspondence July 25, 2014.

[12] Northeast Energy Efficiency Partnership. Technical Reference Manual, Version 4.0, prepared by Shelter Analytics, June 2014. p.261.

HVAC

HVAC O&M benefits would be realized to the extent a new efficient HVAC system incurs fewer repair and maintenance costs than the baseline system. In general, we would expect a new system to require fewer repairs than the in situ system that was replaced. If the HVAC equipment was replaced before the end of its useful life (i.e., was a "retrofit") and the program incentives induced the replacement, then the O&M benefits could be significant. If the in situ system was at the end of its useful life, however, then the benefits would be much smaller, since the relevant comparison would be between the new purchased high efficiency system and the alternative system that would have been replaced if the program did not exist.

We considered including O&M benefits associated with HVAC measures, but decided against it. The main reason was that it is difficult to distinguish between a retrofit HVAC unit and a replace on burnout unit and, as noted above, we were unclear how a new energy efficient HVAC unit would incur significantly lower O&M costs than a new standard efficiency unit. It is unclear whether the incentives provided by the custom programs are sufficient to drive replacement of HVAC systems with any significant remaining life; the default EmPOWER evaluation assumption is that the new efficient HVAC systems are purchased in lieu of alternative standard efficiency units (e.g., SEER 13 central air conditioners).

A secondary reason for not including HVAC measures is that the data were not readily available to allow us to develop O&M benefit estimates for the wide range of HVAC measures incentivized through the EmPOWER programs. In future years, HVAC measures should be given further consideration.

VFDs

O&M benefits are frequently ascribed to VFDs. These benefits are related to the "soft start" capability that VFDs provide. Without VFDs, single-speed motors start abruptly which subjects a motor to very high torque and current surges. A VFD can gradually ramp up the motor to operating speed - hence "soft start." A soft start lessens mechanical and electrical stress on the motor system, which should in theory reduce maintenance and repair costs and extend motor life.

Because VFDs are solid-state devices, increased O&M costs for the VFD units themselves are likely to be non-existent or minimal. However, VFDs can increase harmonic distortion, which could adversely affect power quality and increase maintenance costs associated with other machinery. The additional electrical connections needed, and for some applications the need for a bypass device in the case of VFD unit failure, are also possible O&M issues.

Our conclusion, based on the experience of Itron engineers is that the significant advantages of energy savings and improved process control will far outweigh any peripheral O&M benefits or costs from VFDs. Furthermore, we are not aware of any references that provide quantitative estimates of the O&M impacts associated with VFDs. Consequently, we did not attempt to include VFD O&M benefits in this analysis. In future years, VFDs should be given further consideration.

4.2.4 Develop Algorithms for Calculating the Per-Unit Lamp Replacement Benefits

The calculations used for this analysis are straightforward.[13] The lamp replacement benefits equal the discounted stream of costs associated with baseline lamp replacement minus the discounted stream of costs associated with measure lamp replacement (the base case assumes a 5-percent real discount rate). Lamp replacement savings were calculated with and without labor costs.

The streams of lamp replacement costs were counted over the life of the program measures. For example, C&I programs provide incentives for linear fluorescent fixtures, not linear lamps; thus the annual costs of measure and baseline linear lamp replacements are summed over the measure fixture life. By contrast, where the program measure is the lamp itself (e.g., CFLs and some LEDs), the annual costs of the baseline lamp replacement are summed over the measure lamp life.

The discounted lifetime benefit per lighting measure was multiplied by the number of corresponding measures for each utility. This gave the discounted lamp replacement benefit for each utility program.

Occupancy sensor cost savings result from reduced labor costs. We assumed one minute per day of maintenance staff time per sensor. We then assumed that one minute would be saved 300 days per year, thus totaling five hours per year. We then multiplied by the maintenance wage rate to get annual labor cost. The annual labor cost per sensor was summed over the estimate useful life of an occupancy measure and discounted to calculate the discounted lifetime benefit per sensor. The discounted lifetime benefit per sensor was multiplied by the number of program occupancy sensors installed in each utility program to arrive at the discounted program benefit.

4.2.5 Estimate or Source Input Parameter Values

The most challenging part of this analysis was developing the key parameters required to estimate lamp replacement costs, including: the number of calendar year 2013 program fixtures or lamps, the number of lamps per fixture, measure and baseline lamp prices, measure and baseline EULs, lamp replacement labor hours and wage rates. Development of these parameter

[13] Background calculations are available upon request.

inputs required scrutiny of utility tracking data to develop typical lighting systems that were consistent with tracking system weighted average savings for each measure type.

The sources and methods used to develop each of the parameter assumptions are described in detail below. We were able to develop estimates for all of the utilities' Prescriptive programs and all but PE's SBDI program; the PE SBDI tracking data was not sufficiently detailed to allow us to estimate incandescent replacement costs or occupancy sensors O&M benefits.

Development of the occupancy sensor input parameter was far less involved since it is a relatively uniform and well defined measure.

All parameter assumptions and sources are summarized in Table 4-7.

Table 4-7: Parameter Assumptions and Sources

Labor Costs				
Measure Type	**Labor Hours**	**MD Wage Rate**	**Cost per Replacement**	**Sources[14]**
CFL ROB	0.08	$19.22	$1.54	Labor hours from Itron Measure Cost Study measure name: CFL A-Lamps and Twisters. Hourly Wage Rate from BLS for Maryland Maintenance Worker.
Linear Fluorescent Fixture ROB	0.4	$19.22	$7.69	Labor hours from Efficiency Vermont TRM (p.127) for "T8 3L-F32 w/Elec - 4'" fixture." Hourly Wage Rate from BLS for Maryland Maintenance Worker.
Interior LED ROB	0.13	$19.22	$2.56	Labor hours from Efficiency Vermont TRM (p.127) for "Recessed, Surface, Pendant Downlights." Hourly Wage Rate from BLS for Maryland Maintenance Worker.
Exterior LED ROB	0.13	$19.22	$2.56	Labor hours from Efficiency Vermont TRM (p.127) for "LED Wall Mounted Area Lights." Hourly Wage Rate from BLS for Maryland Maintenance Worker.
Occupancy Sensor	1.25	$19.22	$24.03	Assumes each sensor saves 15 seconds per day of maintenance staff time. Assuming 300 annual work days, that equates to 75 minutes (or 1.25 hours) per year. Hourly Wage Rate from BLS for Maryland Maintenance Worker.
Replacement Lamp Costs				
Measure Type	**Measure Lamp Cost**	**Baseline Lamp Cost**		**Sources**

[14] BLS Maintenance and Repair Workers (#49-9071) – Perform work involving the skills of two or more maintenance or craft occupations to keep machines, mechanical equipment, or the structure of an establishment in repair. Duties may involve pipe fitting; boiler making; insulating; welding; machining; carpentry; repairing electrical or mechanical equipment; installing, aligning, and balancing new equipment; and repairing buildings, floors, or stairs. Excludes "Maintenance Workers, Machinery" (49-9043).

CFL ROB	NA	$1.40		Mid-Atlantic Technical Resource Manual, p.235. TRM value is based on Itron Measure Cost Study, Appendix F, p.13. Assumes CFL replacing 60W halogen incandescent.
Linear Fluorescent Fixture ROB	$23.01	$15.51		Average measure fixture in BGE SBDI and Prescriptive tracking systems contains 3 lamps, so costs multiplied by 3. Mid-Atlantic Technical Resource Manual, p.243. TRM values adapted from Efficiency Vermont Technical Reference Manual 2013-82.5, August 2013.
Interior LED ROB	NA	$9.88		Mid-Atlantic Technical Resource Manual, p.253. Assumes 40% CFLs at $9.70 each and 60% Halogen Par 30-38 lamps at $10 each.
Exterior LED ROB	NA	$28.00		Efficiency Vermont TRM, http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf, p. 127. Assumes 175W pole mounted HID for parking/roadway replaced by 30W-70W LED.
Annual HOU				
Measure Type	**HOU**			**Sources**
SBDI CFL ROB	2,632			HOU equals CFL lamp life divided by weighted average EUL from BGE SBDI tracking system. CFL lamp life from Mid-Atlantic Technical Resource Manual: 10,000 hours.
SBDI Linear Fluorescent Fixture ROB	3,257			HOU = Lamp life / Weighted average EULs from BGE SBDI tracking system. Lamp life from Mid-Atlantic Technical Resource Manual: 35,000 hours for measure lamp, 20,000 for baseline lamp.
SBDI Interior LED ROB	3,830			HOU is from Mid-Atlantic Technical Resource Manual, Appendix D, p.347. Based on EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014
SBDI Exterior LED ROB	4,737			Weighted average annual HOU from BGE SBDI tracking data.
Prescriptive Linear Fluorescent Fixture ROB	3,257			HOU = Lamp life / Weighted average EULs from BGE Prescriptive tracking system. Lamp life from Mid-Atlantic Technical Resource Manual: 35,000 hours for measure lamp, 20,000 for baseline lamp.
Prescriptive Interior LED ROB	3,830			HOU is from Mid-Atlantic Technical Resource Manual, Appendix D, p.347. Based on EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014
Prescriptive Exterior LED ROB	6,208			Weighted average annual HOU from BGE Prescriptive tracking data.
Estimated Useful Life				

Measure Type	Measure Lamp EUL	Baseline Lamp EUL	Measure EUL	Sources
SBDI CFL ROB	3.80	0.38	3.80	Measure EUL = weighted average annual EUL from BGE SBDI tracking data. Baseline EUL = 1,000 hour lamp life / annual HOU.
SBDI Linear Fluorescent Fixture ROB	11.00	6.14	15.00	Measure Lamp is the weighted averages from BGE SBDI tracking system. Baseline Lamp EUL = Lamp life of 20,000 hours/annual HOU. Fixture life from Mid-Atlantic Technical Resource Manual, p.242.
SBDI Interior LED ROB	9.00	1.44	9.00	Baseline lamp EUL = 5,500 lamp hour life / annual HOU for "other" building type from TRM (347). Baseline lamp hour life is based on prescribed TRM (p.253) prescribed 60/40 split between Par lamps with 2,500 hour EUL and CFLs with 10,000 hour EUL. Measure lamp life = 35,000 hour life / annual HOU for "other" building type from TRM (347).
SBDI Exterior LED ROB	13.00	2.11	13.00	Lamp EUL is the weighted average of EUL from BGE SBDI Tracking data. Lamp life from Mid-Atlantic Technical Resource Manual: 10,000 hour HID lamp life (p.282); 70,000 hour LED lamp life (p.280). Annual weighted average HOU from BGE SBDI tracking data.
SBDI Occupancy Sensor	NA	NA	10.00	Mid-Atlantic Technical Resource Manual, p.263.
Prescriptive Linear Fluorescent Fixture ROB	10.75	6.14	15.00	Measure Lamp EUL is the weighted average from BGE SBDI tracking system. Baseline Lamp EUL = Lamp life of 20,000 hours/annual HOU. Fixture life from Mid-Atlantic Technical Resource Manual, p.242.
Prescriptive Interior LED ROB	9.00	1.44	9.00	Baseline lamp EUL = 5,500 lamp hour life / annual HOU for "other" building type from TRM (347). Baseline lamp hour life is based on prescribed TRM (p.253) prescribed 60/40 split between Par lamps with 2,500 hour EUL and CFLs with 10,000 hour EUL. Measure lamp life = 35,000 hour life / annual HOU for "other" building type from TRM (347).
Prescriptive Exterior LED ROB	13.59	1.61	13.59	Lamp EUL is the weighted average of EUL from BGE SBDI Tracking data. Lamp life from Mid-Atlantic Technical Resource Manual: 10,000 hour HID lamp life (p.282); 70,000 hour LED lamp life (p.280). Annual weighted average HOU from BGE SBDI tracking data.
Prescriptive Occupancy Sensor	NA	NA	10.00	Mid-Atlantic Technical Resource Manual, p.263.
SMECO SBDI Linear Fluorescent Fixture ROB	11.00	6.14	15.00	Measure Lamp EUL is the weighted average from SMECO SBDI tracking system. Baseline Lamp EUL = Lamp life of 20,000 hours/annual HOU. Fixture life from Mid-Atlantic Technical Resource Manual, p.242.

SMECO SBDI Interior LED ROB	12.40	1.44	12.40	Baseline Lamp EUL = 5,500 lamp hour life / annual HOU for "other" building type from TRM (347). Baseline lamp hour life is based on prescribed TRM (p.253) prescribed 60/40 split between Par lamps with 2,500 hour EUL and CFLs with 10,000 hour EUL. Measure lamp life = 35,000 hour life / annual HOU for "other" building type from TRM (347).
SMECO Prescriptive Linear Fluorescent Fixture ROB	10.10	6.14	15.00	Measure Lamp EUL is the weighted average from SMECO SBDI tracking system. Baseline Lamp EUL = Lamp life of 20,000 hours/annual HOU. Fixture life from Mid-Atlantic Technical Resource Manual, p.242.
SMECO Prescriptive Interior LED ROB	8.98	1.44	8.98	Baseline Lamp EUL = 5,500 lamp hour life / annual HOU for "other" building type from TRM (347). Baseline lamp hour life is based on prescribed TRM (p.253) prescribed 60/40 split between Par lamps with 2,500 hour EUL and CFLs with 10,000 hour EUL. Measure lamp life = 35,000 hour life / annual HOU for "other" building type from TRM (347).
SMECO Prescriptive Exterior LED ROB	13.11	1.61	13.11	Measure Lamp EUL is the weighted average of EUL from SMECO SBDI Tracking data. Lamp life from Mid-Atlantic Technical Resource Manual: 10,000 hour HID lamp life (p.282); 70,000 hour LED lamp life (p.280). Annual weighted average HOU from SMECO SBDI tracking data.
SMECO Prescriptive Occupancy Sensor	NA	NA	10.00	Mid-Atlantic Technical Resource Manual, p.263.

Sources	
Mid-Atlantic Technical Resource Manual	Northeast Energy Efficiency Partnership. Technical Reference Manual, Version 4.0, prepared by Shelter Analytics, June 2014.
Efficiency Vermont TRM	**Error! Hyperlink reference not valid.**
Itron Ex Ante Measure Cost Study	http://www.energydataweb.com/cpucFiles/pdaDocs/1100/2010-2012%20WO017%20Ex%20Ante%20Measure%20Cost%20Study%20-%20Final%20Report.pdf
Bureau of Labor Statistics (BLS)	http://www.bls.gov/oes/current/oes_md.htm#49-0000.

4.2.6 Calculate the Measure-Level Replacement Benefits

Using the algorithm and parameter values summarized above, we calculated the present value of benefits for each measure for each utility program. These results are reported in Table 4-8 without labor costs and in Table 4-9 with labor costs. Of course without labor costs, no benefits are ascribed to occupancy sensors.

Table 4-8: Measure-Level O&M Benefits Without Labor – 5% Discount Rate

	Per-Unit $ Benefits Without Labor				Total $ Benefits Without Labor		
	PV Unit Costs Over Measure Lifetime						
Measure Type	**Measure ($)**	**Baseline ($)**	**Net PV Unit Benefits Over Measure Life ($)**	**Net PV Unit Benefits Over Measure Life (cents/lifetime kWh saved)**	**NTGR**	**Net # of Units**	**Net PV of Net Benefits Over Life of 2013 Program Measures ($)**
BGE SBDI							
CFL ROB	0.00	12.34	12.34	4.2	0.74	7,368	90,898
LF Fixture ROB	14.83	20.64	5.81	0.1	0.74	44,324	257,509
Exterior LED Lighting ROB	0.00	115.29	115.29	0.8	0.74	4,207	485,032
BGE Prescriptive							
LF Fixture ROB	15.57	29.13	13.56	0.3	0.72	50,074	679,041
LED ROB	0.00	47.95	47.95	2.5	0.72	31,623	1,516,304
Exterior LED Lighting ROB	0.00	155.95	155.95	1.4	0.72	9,426	1,469,904
Occupancy Sensor	0.00	0.00	0.00	0.0	0.72	25,577	0
PEPCO SBDI							
LF Fixture ROB	14.83	20.64	5.81	0.1	0.74	49,033	284,869
LED ROB	0.00	47.95	47.95	2.3	0.74	48,039	2,303,448
Occupancy Sensor	0.00	0.00	0.00	0.0	0.74	7,676	0
PEPCO Prescriptive							
LF Fixture ROB	15.57	29.13	13.56	0.2	0.72	5,424	73,560
LED ROB	0.00	47.95	47.95	1.1	0.72	21,829	1,046,682
Occupancy Sensor	0.00	0.00	0.00	0.0	0.72	3,853	0
DPL SBDI							
LF Fixture ROB	14.83	20.64	5.81	0.1	0.74	3,868	22,472
LED ROB	0.00	47.95	47.95	2.2	0.74	21,925	1,051,309
Occupancy Sensor	0.00	0.00	0.00	0.0	0.74	4,392	0
DPL Prescriptive							
LF Fixture ROB	15.57	29.13	13.56	0.2	0.72	3,344	45,343
LED ROB	0.00	47.95	47.95	1.5	0.72	5,195	249,087
Occupancy Sensor	0.00	0.00	0.00	0.0	0.72	1,089	0
SMECO SBDI							
LF Fixture ROB	14.83	20.64	5.81	0.1	0.74	2,016	11,711
LED ROB	0.00	59.79	59.79	1.0	0.74	865	51,723

SMECO Prescriptive							
LF Fixture ROB	15.57	29.13	13.56	0.5	0.72	6,180	83,812
LED ROB	0.00	47.95	47.95	2.7	0.72	1,167	55,962
Exterior LED Lighting ROB	0.00	155.95	155.95	1.4	0.72	348	54,233
Occupancy Sensor	0.00	0.00	0.00	0.0	0.72	1,053	0
PE Prescriptive							
LF Fixture ROB	15.57	29.13	13.56	0.2	0.72	10,069	136,546
Exterior LED Lighting ROB	0.00	47.95	47.95	1.8	0.72	10,104	484,467
Exterior LED	0.00	155.95	155.95	1.5	0.72	1,440	224,567
Occupancy Sensor	0.00	0.00	0.00	0.0	0.72	2,557	0
Note: The PE SBDI program was not included due to insufficient tracking data detail.							

Table 4-9: Measure-Level O&M Benefits Including Labor – 5% Discount Rate

Measure Type	Per-Unit $ Benefits Including Labor				Total $ Benefits Including Labor		
	PV Unit Costs Over Measure Lifetime		Net PV Unit Benefits Over Measure Life ($)	Net PV Unit Benefits Over Measure Lifetime (cents/lifetime kWh saved)	NTGR	Net # of Units	Net PV of Net Benefits Over Life of 2013 Program Measures ($)
	Measure ($)	Baseline ($)					
BGE SBDI							
CFL ROB	0.00	25.89	25.89	8.8	0.74	7,368	190,730
LF Fixture ROB	19.79	30.87	11.09	0.3	0.74	44,324	491,369
Exterior LED Lighting ROB	0.00	125.85	125.85	0.8	0.74	4,207	529,424
BGE Prescriptive							
LF Fixture ROB	20.78	43.58	22.80	0.4	0.72	50,074	1,141,624
LED ROB	0.00	57.51	57.51	3.0	0.72	31,623	1,818,668
Exterior LED Lighting ROB	0.00	170.22	170.22	1.5	0.72	9,426	1,604,435
Occupancy Sensor	0.00	185.51	185.51	8.1	0.72	25,577	4,744,961
PEPCO SBDI							
LF Fixture ROB	19.79	30.87	11.09	0.3	0.74	49,033	543,576
LED ROB	0.00	57.51	57.51	2.7	0.74	48,039	2,762,776
Occupancy Sensor	0.00	185.51	185.51	10	0.74	7,676	1,424,014

PEPCO Prescriptive							
LF Fixture ROB	20.78	43.58	22.80	0.3	0.72	5,424	123,672
LED ROB	0.00	57.51	57.51	1.3	0.72	21,829	1,255,399
Occupancy Sensor	0.00	185.51	185.51	3.7	0.72	3,853	714,736
DPL SBDI							
LF Fixture ROB	19.79	30.87	11.09	0.3	0.74	3,868	42,880
LED ROB	0.00	57.51	57.51	2.6	0.74	21,925	1,260,949
Occupancy Sensor	0.00	742.06	742.06	6.6	0.74	4,392	814,762
DPL Prescriptive							
LF Fixture ROB	20.78	43.58	22.80	0.3	0.72	3,344	76,232
LED ROB	0.00	57.51	57.51	1.8	0.72	5,195	298,757
Occupancy Sensor	0.00	185.51	185.51	5.3	0.72	1,089	202,092
SMECO SBDI							
LF Fixture ROB	19.79	30.87	11.09	0.3	0.74	2,016	22,346
LED ROB	0.00	71.71	71.71	1.2	0.74	865	62,037
SMECO Prescriptive							
LF Fixture ROB	20.78	43.58	22.80	0.8	0.72	6,180	140,908
LED ROB	0.00	57.51	57.51	3.3	0.72	1,167	67,122
Exterior LED Lighting ROB	0.00	170.22	170.22	1.5	0.72	348	59,197
Occupancy Sensor	0.00	185.51	185.51	6.4	0.72	1,053	195,280
PE Prescriptive							
LF Fixture ROB	20.78	43.58	22.80	0.3	0.72	10,069	229,566
LED ROB	0.00	57.51	57.51	2.1	0.72	10,104	581,074
Exterior LED Lighting ROB	0.00	170.22	170.22	1.7	0.72	1,440	245,120
Occupancy Sensor	0.00	185.51	185.51	3.8	0.72	2,557	474,309
Note: The PE SBDI program was not included due to insufficient tracking data detail.							

4.2.7 Estimate Impact of Lamp Replacement Benefits on Utility Program-Level TRC Benefit Cost Estimates

For each measure, the present value per-unit lamp replacement benefits and per-unit occupancy sensor benefits were multiplied by the number of corresponding units to calculate the present value total lamp replacement benefits. For each utility program, the present value total benefits were then summed.

The present value O&M benefits were then added to the present value electric benefits from the preliminary 2013 EmPOWER cost effectiveness analysis of the 2013 Prescriptive and SBDI programs. All calculations are done separately for lamp replacement benefits with labor and lamp replacement benefits without labor.

4.3 Results and Application

The TRC results for the Prescriptive programs without O&M benefits are shown in Table 4-10 and the results with O&M benefits are shown in Table 4-11.

Table 4-10: 2013 C&I Prescriptive Program Total Resource Cost Effectiveness – Without O&M Benefits

Utility	PV Total Benefits ($)	PV Costs ($)	TRC B/C Ratio
BGE	53,559,467	22,078,288	2.43
DPL	6,954,317	2,194,279	3.17
PE	3,270,063	3,330,411	0.98
Pepco	39,524,703	9,275,614	4.26
SMECO	2,860,625	1,176,407	2.43
Statewide	**106,169,175**	**38,054,999**	**2.79**

Table 4-11: 2013 C&I Prescriptive Program Total Resource Cost Effectiveness – Including O&M Benefits

Utility	Without Labor Costs			With Labor Costs		
	NPV O&M Benefits ($)	PV Total Benefits including O&M ($)	TRC B/C Ratio	NPV O&M Benefits ($)	PV Total Benefits including O&M ($)	TRC B/C Ratio
BGE	3,665,248	57,224,715	2.59	9,309,689	62,869,156	2.85
DPL	294,430	7,248,747	3.30	577,081	7,531,398	3.43
PE	845,581	4,115,644	1.24	1,530,070	4,800,133	1.44
Pepco	1,120,242	40,644,945	4.38	2,093,807	41,618,510	4.49
SMECO	194,008	3,054,633	2.60	462,506	3,323,131	2.82
Statewide	**6,119,508**	**112,288,683**	**2.95**	**13,973,153**	**120,142,328**	**3.16**

The TRC results for the SBDI programs without O&M benefits are shown in Table 4-12 and the results with O&M benefits are shown in Table 4-13.

Table 4-12: 2013 SBDI Program Total Resource Cost Effectiveness – Without O&M Benefits

Utility	PV Total Benefits ($)	PV Costs ($)	TRC B/C Ratio
BGE	22,923,537	13,939,265	1.64
DPL	13,017,430	7,414,614	1.76
PE	295,010	1,010,961	0.29
Pepco	71,257,078	23,303,199	3.06
SMECO	917,011	814,595	1.13
Statewide	**108,410,067**	**46,482,634**	**2.33**

Table 4-13: 2013 SBDI Program Total Resource Cost Effectiveness – Including O&M Benefits

Utility	Without Labor Costs			With Labor Costs		
	NPV O&M Benefits ($)	PV Total Benefits including O&M ($)	TRC B/C Ratio	NPV O&M Benefits ($)	PV Total Benefits including O&M ($)	TRC B/C Ratio
BGE	833,439	23,756,976	1.70	1,211,523	24,135,060	1.73
DPL	1,073,781	14,091,211	1.90	2,118,591	15,136,021	2.04
PE*	NA	295,010	0.29	NA	295,010	0.29
Pepco	2,588,317	73,845,395	3.17	4,730,366	75,987,444	3.26
SMECO	63,434	980,445	1.20	84,384	1,001,395	1.23
Statewide	**4,558,970**	**112,969,037**	**2.43**	**8,144,863**	**116,554,930**	**2.51**

*The PE SBDI program was not included due to insufficient tracking data detail.

Table 4-13 presents the ratios of TRC Benefit Cost Ratios with O&M benefits to TRC Benefit Cost Ratios without O&M benefits for each utility's Prescriptive and SBDI program including labor. Statewide, if lamp replacement and occupancy sensor benefits were included, the TRC benefits would increase by 13 percent for Prescriptive programs and 8 percent for the SBDI programs. PE's Prescriptive program would receive the greatest percentage boost, with its TRC increasing by nearly one-half.

Table 4-14: Ratio of TRC with O&M Benefits to TRC without O&M Benefits

Utility	Prescriptive	SBDI
BGE	1.17	1.05
DPL	1.08	1.16
PE	1.47	NA
PEPCO	1.05	1.07
SMECO	1.16	1.09
Statewide	1.13	1.08

For the Cost Effectiveness Working Group for the EmPOWER Potential Study, we recommend that the O&M benefits including labor costs be used in all of the cases. Starting with the PY2014 ex post cost effectiveness analysis, we recommend these benefits including labor costs be included in the TRC test, as well as the participant test and societal test if those tests are included in the ex post analyses.

We can provide either or both annual benefits or lifetime present value benefits upon request. The values should be multiplied by the number of measure units that were induced by the program – the number of units should be adjusted to reflect free riders. If annual values are used, a price inflation escalator should be applied. Undiscounted annual benefits are provided in Chapter 6.

These are participant O&M benefits from installing more efficient lamps and fixtures in commercial and industrial sites are analogous to the O&M benefits that have been included in the ex post cost effectiveness analyses of the residential lighting programs since 2011. Calculation of these benefits is reasonably straight forward and all assumptions are provided and can easily be amended if the Cost Effectiveness Working Group or the Commission thinks it is appropriate. If these O&M benefits are determined to not be appropriate to include in the TRC test, then we recommend that the benefits currently included and quantified for residential incandescent replacements be excluded as well.

5

Arrearage

5.1 Introduction

Utilities across the country find high levels of arrearage[1] time-consuming and expensive. Arrearages cost utilities money as they are essentially loaning money to their customers until arrearages are paid off. While a portion of arrearages can be recovered in late payment charges, these charges also often remain unpaid. Energy efficiency programs resulting in higher rates of on-time customer bill payment offer utilities additional benefits beyond the value of energy and demand savings. Utilities can reduce arrearage levels by offering programs—particularly for low income customers—that reduce customers' energy bills[2], thus making it easier for them to their pay bills on time.

Arrearage savings have been documented extensively over the past 20 years by utilities across the country. The savings associated with arrearage reductions are commonly cited as "non-energy benefits." Previous arrearage studies are often combined with qualitative or quantitative survey efforts in order to understand what the customer valued about the program and what led to their increased ability to pay their utility bill.[3]

The following is a list of bill payment-related benefits identified in the literature:

1. Carrying costs on arrearages (utility)
2. Reduced bad debt write-offs (utility)
3. Reduced costs for bill collection process (utility)
4. Reduced levels of disconnects / connects (shut-offs) (utility)
5. Reductions in low income subsidies and payments (utility)
6. Increased ability to pay utility bill (participant)
7. Increased levels of disposable income (participant)
8. Improvements to income equity (societal benefit)

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[1] Arrearage is the amount of unpaid bills accruing to a utility customer.

[2] Electric and Gas savings are included in these saving estimates

[3] Note: There are NEBs associated with reduced arrearage for customers other than low income; however, the savings to the utility are not as high. Consequently, this is not an area that utilities have spent much time researching.

While this list suggests there are a large number of non-energy payment-related benefits accruing to customers and society, in this chapter, our examination will focus solely on the quantification of "utility" arrearage reduction benefits (#1 on list above – carrying costs on arrearages) that accrue directly to the utility from a larger number of customers paying their bills on time. Arrearage reductions due to "low income" customer program participation have been shown repeatedly to exist in numerous studies across the country. Relatively few studies have been completed that quantify the arrearage benefits from programs delivered to the general population. If this information is desired, we would recommend that these benefits to the general population be quantified through Maryland specific research.

Our recommendation is for the Maryland utilities to either use a documented two percent savings estimate (details of how this two percent was derived are detailed section 5.2 below), or to conduct utility-specific studies on payment-related benefits, specifically arrearage studies for Maryland low income programs. These primary research efforts would provide a detailed understanding of differences in bill payment rates between participants and non-participants in these programs and show how these translate into reductions in financial costs for Maryland utilities. In addition some of the other non-energy benefits from low income programs listed above could be investigated. However, while not specific to Maryland, there appears to be enough research conducted nationwide in the past ten years to justify using secondary research to quantify arrearage benefits for low income programs in Maryland. While the savings per customer are small, leaving these benefits on the table and out of the TRC test underestimates the total value of the energy efficiency investments made by customers to society and the direct financial benefits to the utility.

A recent ACEEE report[4] that surveyed state policies does not go into detail on which utility non-energy benefits are included in cost-effectiveness tests, and a recent Synapse Energy Economics study[5] of state policies in eight eastern states includes arrearages as part of a larger "utility other program impacts" category, which includes arrearages as well as other utility perspective benefits.

Arrearage benefits accruing to the utility should be applied to the TRC test because these reductions in costs are real savings to utility program administrators and, as such, should be included with other utility cost impacts. The recommended values we suggest are in terms of the carrying cost to the utility of holding short term debt due to customer arrearages. Studies across the country show proven arrearage reduction from energy efficiency measures in limited income households. Arrearage reductions resulting from energy efficiency measures in non-limited

4 Kushler, Martin, Seth Nowak, and Patti White. A National Survey of State Policies and Practices for the Evaluation of Rate-Payer Funded Energy Efficiency Programs. ACEEE Report U122. February 2012.

5 Wolf, Tim, Erin Malone, Jenn Kallay, and Kenji Takahashi. *Energy Efficiency Cost Effectiveness Screening in Northeast and Mid-Atlantic States*. Synapse Energy Economics Inc. October 2013.

income programs are also sometimes cited, but the reductions are significantly lower and likely not worth quantifying. We recommend that arrearage benefits only be applied to the energy savings from the Maryland limited income program.[6]

5.2 Literature Review

Our team reviewed ten arrearage reports completed over the past 10 years. For this analysis, our team focused on the four studies (described below) that we feel are the most relevant to Maryland based on their comprehensiveness and recent dates of completion.

5.2.1 SERA Inc. Research

The first two studies are a compilation and analysis of dozens of reports analyzed by Skumatz Economic Research Associates, Inc. (SERA) for the California Public Utilities Commission (CPUC) and the NRDC (for Maryland).

In 2010, SERA authored a report[7] for California where the CPUC required that utility program managers account for utility and participant low income benefits such as reduced shutoffs and calls to the utility, lower levels of relocation, and perceived benefits in comfort. The report documents the results from numerous studies on arrearage reductions and indicates a wide range of values for reduced arrearage. Most program participants report the value of benefits caused by the program is in the range of 20-30 percent of dollar value of the annual energy savings. The reduction in arrearage caused by efficiency investments was estimated at 20-25 percent of the total arrearage value. The dollar values in annual carrying cost reduction range from $2–$32 per participant. Evaluations of the arrearage effect of low income programs report significantly higher arrearage cost savings, especially if participants with arrearages are targeted.

The findings in Table 5-1 are based on 15 low-income payment studies across the country. In 2014, SERA produced a report specifically for Maryland[8] that recommends an arrearage reduction benefit of two percent of retail bill savings, or roughly $2.50 - $4.00 per participant. This estimate is based on the results of SERA's 2010 California study (Table 5-2), which was a compilation of non-energy benefit studies across the country. The report recommends a higher arrearage reduction benefit of up to 16 percent of retail bill savings ($13 per participant) if low-income subsidies are avoided.

6 Arrearage reductions are found to be the greatest in programs that specifically target high arrearage customers; Maryland programs however do not specifically target high arrearage customers.

7 Skumatz, Lisa. Non-Energy Benefits: Status, Findings, Next Steps, and Implications for Low-Income Program Analysis in California. SERA Inc. May 2010.

8 Skumatz, Lisa. Non-Energy Impacts / Non-Energy Impacts and Their Role and Values in Cost Effectiveness Tests, State Of Maryland. SERA Inc. March 2014.

Table 5-1: Weatherization Non-Energy Benefit Value Ranges – SERA 2014

NEB Estimates from Multiple Weatherization Studies: Dollar and Percentage Analysis	Dollar NEB Values Range Low-High		Typical Value	Percent NEB Values Range Low-High		Typical Value	Notes
UTILITY PERSPECTIVE							
Payment-related							
Carrying cost on arrearages	$1.50 -	$4.00	$2.50	0.6% -	4.4%	2.0%	Total arrearages $2-$100; $20-30 typical
Bad Debt Write-offs	$0.50 -	$3.75	$1.75	0.4% -	2.0%	0.7%	
Reduced LI subsidy pymt/discounts	$3.00 -	$25.00	$13.00	3.9% -	29.0%	16.4%	IF low income program
Shutoffs / Reconnects	$0.10 -	$3.65	$0.65	0.1% -	4.4%	0.5%	
Notices	$0.05 -	$1.50	$0.60	0.1% -	1.8%	0.9%	
Customer calls / collections	$0.40 -	$1.60	$0.90	0.2% -	1.9%	0.6%	
Service Related							
Emergency / safety	$0.10 -	$8.50	$3.25	0.1% -	2.7%	0.8%	Few good studies
Other Primary Utility							
Insurance savings	$0.00 -	$0.00	$0.00	1.2% -	1.2%	1.2%	Few studies
T&D savings (usually distrib)	$0.13 -	$2.60	$1.40	0.9% -	2.1%	1.2%	Straightforward, but few studies
Fewer substations / infra	$0.00 -	$0.00	$0.00	0.0% -	0.0%	0.0%	Impt / needs more studies
Power quality / reliability	$0.00 -	$0.00	$0.00	0.0% -	0.0%	0.0%	Important; value of service study approach
Other Primary Utility	$0.00 -	$0.00	$0.00	0.0% -	0.0%	0.0%	
TOTAL UTILITY NEBs	$5.78 -	$50.60	$24.05	7.4% -	49.5%	24.4%	
UTILITY NEBs MULTIPLIER	3% -	25%	12%	0.4% -	14.8%	3.3%	

Source: Table 3.4: Non-Energy Impacts / Non-Energy Impacts and Their Role and Values in Cost Effectiveness Tests, State Of Maryland, SERA Inc., March 2014, p. 28.

Table 5-2: Results from Low-Income Payment Studies in California Report – SERA 2010

ID Perspective or NEB Category	Summary of Values (per participant / yr.); Implications
UTILITY PERSPECTIVE	
Carrying Cost on Arrearages	Estimates of arrearage for programs targeted at general low income population range from 20-30% of annual bill savings. Dollar values range from $2/participant, to $32/part; (several in range of $60). Estimated arrearage savings are higher for programs targeting high arrearage customers
Bad Debt Written Off	Impact values usually in the 20-35% range; not many studies specifically on this feature. Values $60+ for those affected, $2 when averages across all participants.
Shutoffs	Values on order of $2 or less for many utilities; several found very high values ($100+)
Reconnects	Net values from pennies to $50+ reconnect charge (many did not multiply times incidence)
Notices	Few study these separately
Customer Calls / Bill or Emergency-Related	Values on order of $0.50.
Other Bill Collection Cost	Few study these separately.
Emergency Gas Service Calls (for gas flex connector and other programs)	Based on 2 main studies – Magouirk and Blasnik.
Insurance Savings	Very rarely examined
Transmission and Distribution Savings (usually distribution)	Not often separately studied; embedded in utility avoided costs for some. Rules of thumb estimated percentages for some.
Fewer Substations, etc.	Not studied to date
Power Quality / Reliability	Not studied to date
Reduced Subsidy Payments (low income)	Very directly related to the energy savings and utility's discount rate
Other	Not available
Total Perspective Utility	**Lowest of the 3 perspectives. Totals range from $4-$31/HH.**

Source: Table 4.1: Values for NEBs for Low Income Programs for Utilities around the Country. Non-Energy Benefits Report, SERA Inc., May 2010, p. 25.

5.2.2 Massachusetts Study

A study for Massachusetts program administrators[9] conducted by Tetra Tech and Nexus Market Research in 2011 indicates that the value of reduced carrying cost on arrearages ranges from \$1.37 - \$4.00 per participant, depending on the population targeted and method of analysis used. Table 5-3 shows results from low-income weatherization programs. The study indicates that comparison of arrearage saving estimates across multiple evaluations of low income programs is difficult for at least two reasons. First, these studies do not consistently report differences in the energy and dollar savings achieved by participants who are likely to lead to different levels of reduction in the absolute dollar amount of delinquent bills owed to utilities. Second, it is likely that carrying charges or interest rates applied to this debt load are different across utilities.

Table 5-3: Results of Low-Income Arrearage Studies in Massachusetts Report

Study	Reported NEI Value, \$/year/participant					
	Carrying Cost on Arrearages	Bad Debt Write-Offs	Terminations and Reconnections	Customer Calls	Notices	Safety-Related Emergency Calls
WI Low-income Weatherization (Skumatz and Gardner, 2005)	1.37	--	0.13	0.43	0.30	--
National Low-income Weatherization NEBs Study (Schweitzer and Tonn, 2002)	--	6.09	0.55	--	--	6.91
MA Low-income Weatherization (Skumatz Economic Research) Associates, 2002)	1.71	3.62	--	0.59	--	0.40
CT Low-income Weatherization (Skumatz and Nordeen, 2002)	2.03	2.24	0.10	0.55	1.16	0.21
CA Low-income Public Purpose Test (TecMarket Works, Skumatz Economic Research Inc, and Megdal Associates, 2001)	3.76	0.48	0.07	1.58	1.49	0.07
VT Low-income Weatherization (Riggert et al., 1999)	--	--	7.00	--	--	15.58
CA Low-income Weatherization (Skumatz and Dickerson, 1999)	2.09	2.34	0.33	0.07	0.04	7.91
Venture Partners Pilot Program (Skumatz and Dickerson, 1997)	4.00	4.50	0.63	0.13	0.08	15.00

Source: Table 4-2: Reported NEI Values (Dollars per Participant per Year) from Recent NEI Studies of Low-Income Programs. Massachusetts NEI Evaluation, August 2011

5.3 Methods Assessment

The studies we reviewed use a pre-post treatment/comparison group method to estimate average arrearage reductions across low income programs. Typically this means that one year of billing data pre-treatment and one year of billing data post-treatment is analyzed and the difference in

9 Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Tetra Tech and Nexus Market Research. August 2011.

total arrearage reduction for the utility is calculated for a random sample of low-income program participants. This arrearage reduction is then compared to arrearage levels for a random sample of low-income utility customers who did not receive energy efficiency treatments to account for economic conditions, weather, and other external conditions that may affect ability to pay. Any arrearage reduction in the sample of non-treated customers is then subtracted from arrearage reduction in the sample of low-income customers who did receive energy efficiency treatments to get the net effect of the treatment on arrearage reduction. This method results in an unbiased estimate of arrearage reduction when a robust sample of utility customer bills is studied. If desired, Maryland utilities could consider conducting their own arrearage reduction studies with a similar methodology for either low income programs or perhaps using the same methodology to estimate potential arrearage impacts at the portfolio level.

Until such studies are completed, Itron agrees with the SERA NRDC arrearage recommendation for Maryland which (based on the comprehensive SERA/Cadmus California report estimated as the average reduction in carrying cost from the results of 15 arrearage studies). Our research found that the most comprehensive review of arrearage studies is contained in the California Low-Income study by SERA[10] (shown in Table 5-2).

5.4 Credibility of Sources

The results reported in the two SERA studies are credible for use in Maryland due to the extensive secondary research contained in them. These studies contain the largest review of arrearage reduction study results in terms of utility carrying cost reduction. The two percent of bill savings recommendation ($2.50 - $4.00) from the SERA study is consistent with the arrearage benefit recommendation in the Massachusetts study[11] of $0.50 - $7.50 per low-income participant.

The studies meet several important criteria and standards:

- They describe a plausible hypothesis for what causes arrearage reductions.
- They entertain the possibility that there may be costs, rather than benefits, related to the installation of energy efficiency measures.
- Estimates of arrearage reductions report fairly consistent values from the 1990's to those studies completed in the early 2000's.
- Interest rates and the fraction of customers who qualify for low income status have been fairly consistent over the last decades.

10 Non-Energy Benefits Report, SERA Inc., May 2010.
11 Massachusetts NEI Evaluation, August 2011.

- Estimates were conducted by experienced third party consultants who are not advocates or affiliated with any advocacy groups.
- The studies were reviewed by utility clients and their stakeholders before final publication.

5.5 Key Assumptions

5.5.1 Maryland Limited Income Customers Have Similar Payment Patterns to Customers in Other States

Using the average arrearage reduction values found for low-income program participants in other states means that we believe that Maryland low-income participants would behave in a similar manner as participants in other states with the extra money available due to energy bill savings. We believe this is a reasonable assumption since the value is based on a large number (15) of arrearage studies where the characteristics of the low income populations and building stock studied are similar to the conditions in Maryland.

5.5.2 The Amount of Arrearage Reduction Cost is Linearly Related to Bill Savings

The amount of bill savings achieved by programs depends on the mix of measures in low-income programs. This mix is dependent both on participant investment and utility funding as well as differences in climate and baseline conditions. It is possible that very high bill savings in some states will result in greater arrearage reductions, or very low bill savings per customer will result in significantly lower arrearage reductions. We do not currently have a method to investigate this issue with the absence of a Maryland-specific arrearage study.

5.6 Concerns and Uncertainties

The following sections discuss some of the concerns expressed by the Maryland utilities and stakeholders during an initial review of arrearage benefits. The Itron team researched these issues. Our analysis and recommendations are included below.

5.6.1 Interaction with Late Payment Charges

Issue raised: Is it possible that estimating benefit values for arrearage reductions may be unnecessary because some or all of the cost to the utility is made up by late payment charges to customers?

Response: The benefits of reducing arrearage costs are both a benefit to participants and to the utility regardless of whether utilities can recover some of the revenue lost through late payment charges. The utility, customer and society are all better off in a market where customer bills get paid on time, levying late charges simply increases the transactions costs to all involved and in most cases will result in a bill increase for everyone because late charges do not cover all of the carrying costs for bad debt.

While at first glance, there appears to be merit in this question, almost all utilities levy late payment charges on customers and yet arrearage studies still find utility benefits in arrearage reductions from energy efficiency measures. In addition, even though the utility may levy a late payment charge, this amount will also likely remain unpaid and is just added to the total level of customer arrearage (or carrying costs on unpaid bills due).

We would argue that even if these late charges potentially make up for the loss in utility revenue due to increased carrying costs, both charges are a net loss to society and likely to result in higher rates for all ratepayers. Thus the primary focus should be on reducing the proportion of customers who pay their bill late, regardless of whether the utility can recoup these arrearage costs in base rates or late payment changes later. If the Maryland stakeholders feel that this is still an issue, our suggestion is that the "late payment charge" topic should be examined within the a new study gathering data on arrearage costs across the Maryland population segments of interest.

5.6.2 Interaction with Other Low-Income Payment Assistance Programs

Issue Raised: Maryland utilities and non-profits have several forms of low-income payment assistance programs available to low income households in addition to the utility or DHCD offered low income energy efficiency programs. Savings from the energy efficiency programs may affect eligibility for participation in other assistance programs and have a feedback or interactive effect on the likelihood that energy bills from participants will be paid on time.

Response: While we recognize that these interactive effects may affect the estimate of the average arrearage cost savings due solely to utility energy efficiency programs, we are confident that several other states also offer multiple programs available to local low income populations and the potential interactive effect from these other programs did not have any material effect on the estimated arrearage reductions per customers. This interactive effect can be controlled for as long as the sample design is designed to ensure the treatment group only contains participants in low income programs who are not simultaneously participating in other programs. In either event, our recommendation would be for utilities, if desired, to quantify the benefit for either their programs only or for all assistance programs through primary research.[12]

[12] Research shows arrearage benefits from 2 percent to 16 percent (or $13 per participant depending on the level of payment assistance avoided. Skumatz, Lisa. *Non-Energy Impacts / Non-Energy Impacts and Their Role and Values in Cost Effectiveness Tests, State Of Maryland*. SERA Inc. March 2014

5.7 Recommended Values

Our recommendation for Maryland is that a conservative estimate in the lower end of the range of published estimates - equivalent to two percent of bill savings - be used to value arrearage reductions. By conservative, we mean the recommended value is within the lowest quartile or 25 percent of estimates found in the literature. The expected value or mean estimate would be closer to 4 percent of bill savings but given the uncertainties in transferring this value across states, we recommend the conservative value.

The latest verified impact evaluation for the EmPOWER limited income programs was for the 2011 program year. The 2011 EmPOWER Limited Income evaluation documented average participant savings of 1,945 kWh per year which result in an average of $253 of bill savings per year, as shown in Table 5-4. Applying a 5% real discount rate over the weighted average life of the 2011 limited income programs, the lifetime arrearage financing benefit was $55 per participant.

Table 5-4: Arrearage Reduction Recommendation for Maryland

	Annual kWh Savings per Program Participant[13]	Annual Retail Bill Savings per Participant[14]	Lifetime Present Value Arrearage Carrying Cost per Participant[15]
Arrearage Reduction Recommendation	1,945	$253	$55

5.8 Impact on Program Cost Effectiveness

We recommend that this $55 benefit be added to the present value benefits when calculating the Limited Income program TRC benefit/cost ratio. Alternatively, a benefit equal to 2% of each kWh saved over the life of the measures could be applied. Incorporating the arrearage financing cost benefit into the cost effectiveness analysis of limited income programs would increase the statewide program TRC by roughly 1.5%. The statewide TRC benefit/cost ratio for the programs was 0.446. If the arrearage financing cost benefit had been included, the TRC benefit/cost ratio would have been 0.453. If the arrearage financing cost benefit was also applied to gas utility bill savings, the TRC benefit/cost would increase by nearly 2% since most of the non-electric benefits counted in the 2011 analysis was from gas savings.

[13] Navigant Consulting, Empower Maryland 2011 Evaluation Report, Chapter 8: Limited Income Programs, March 8, 2012, pp.7-8.

[14] Based on May 2013 average statewide residential electric rate of 13 cents per kWh from US Energy Information Administration, Electric Power Monthly, July 28, http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

[15] Based on 2% of electric bill savings using a 5% real discount rate.

Savings due to carrying cost reductions are small and have remained fairly stable and somewhat consistent over time and location. However, if desired, Maryland utilities can conduct a study of utility arrearage reductions attributable to low income program participants if a more accurate estimate of non-energy benefits associated with measures installed in low income households is desired. Previous primary research has tended to use a pre/post treatment/comparison methodology to quantify these reduced arrearage benefits and benefits to the low income participants themselves. Given that Itron is recommending that a similar pre/post research design be used to verify the energy saving from the low income program in 2014, the incremental cost of completing this NEB analysis could be quite low.

Interviews with program participants could be used to research the savings attributable to low-income subsidy payment reductions available from other programs and also to obtain an understanding of the value that participants obtain through program participation and the factors that enabled them to pay their bills more promptly. However it is important to note that the relatively small benefit of two percent for arrearages alone suggests that a larger scope that might examine all or most of the non-energy benefits associated with these programs might be more cost efficient for the utilities.

We estimate the incremental cost of estimating the potential effect of low income programs on utility arrearages in Maryland to be roughly $10,000 assuming a sample size of 100 participants and 100 controls. This is the cost to the evaluation team. We do not have any knowledge of how difficult or easy it would be for the host utility to match late payment records with sample participants and provide the interest rate used to accrue carrying charges on late bills. We suggest this topic be discussed during the next available working group meeting of the low income group to assess the level of interest in this topic.

6

Summary of Recommendations

Four non-energy benefits were estimated as part of this analysis: air emissions, comfort, commercial operations and maintenance (O&M), and utility bill arrearages. In all four cases, we provide a recommended value and methods for including them in future ex ante and ex post EMPOWER costs effectiveness analyses.

This is not a comprehensive estimate of all potential non-energy benefits associated with the EmPOWER programs, nor even of the four individual benefits categories. Many types of benefits were not covered in this analysis. However, including these benefits would greatly improve the accuracy of future EmPOWER cost effectiveness analyses and better align those analyses with EmPOWER policy objectives.

Below, we summarize the recommended values and methods for applying them in EmPOWER cost effectiveness analyses.

Table 6-1 Summary of Recommended Values and Application

Benefit	Case	Programs	Value	Basis	B/C Test
Air Emissions	Medium Case (Recommended)	All	1.1 cents	Should be multiplied by all kWh saved for the life of each measure and then multiplied by the NTG ratio for each measure. Values are in 2014 dollars; a price inflation escalator should be applied.	TRC, SCT
	High Case		2.2 cents		
	Low Case		0.2 cents		
Comfort	Medium Case (Recommended)	HPwES and Low Income	HPwES: $136 Low Income: $110	Values should be multiplied by the number of comprehensive air sealing participants for each year of the measure life and then multiplied by 1 minus the free ridership rate. Values are in 2014 dollars; a price inflation escalator should be applied.	PCT, TRC, SCT
	High Case		HPwES: $204 Low Income: $165		
	Low Case		HPwES: $34 Low Income: $27		
C&I O&M	Medium Case (Recommended)	C&I Prescriptive and SBDI	Varies by measure (see Table 6-2)	Should be multiplied by the number of measure units that were induced by the program and then multiplied by 1 minus the free ridership rate. Annual and/or discounted lifetime benefits are available upon request. Values are in 2014 dollars; if annual values are used, a price inflation escalator should be applied.	PCT, TRC, SCT
	High Case				
	Low Case				
Arrearages	Medium Case (Recommended)	Limited Income	2% of kWh savings.	Should be applied to all kWh saved over the life of the measures installed as part of the program and then multiplied by 1 minus the free ridership rate.	PAC (UCT), TRC, SCT
	High Case				
	Low Case				

Table 6-2 C&I Prescriptive and SBDI Program O&M Benefits

Utility Program	Measure Type	O&M Net Benefits Per Measure Unit (2014 $)														
		Year														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
BGE SBDI	SBDI CFL ROB	7.73	7.73	7.73	5.88	-	-	-	-	-	-	-	-	-	-	-
BGE SBDI	SBDI Linear Fluorescent Fixture ROB	-	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-
BGE SBDI	SBDI Exterior LED ROB	-	-	30.56	-	30.56	-	30.56	-	30.56	-	30.56	-	30.56	-	-
BGE Prescriptive	Prescriptive Linear Fluorescent Fixture ROB	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-	23.20
BGE Prescriptive	Prescriptive Interior LED ROB	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	-	-	-	-	-
BGE Prescriptive	Prescriptive Exterior LED ROB	-	30.56	-	30.56	30.56	-	30.56	-	30.56	30.56	-	30.56	30.56	-	-
BGE Prescriptive	Occupancy Sensor	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	-	-	-	-	-
PEPCO SBDI	SBDI Linear Fluorescent Fixture ROB	-	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-

PEPCO SBDI	SBDI Interior LED ROB	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	-	-	-	-	-
PEPCO SBDI	Occupancy Sensor	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	-	-	-	-	-
PEPCO Prescriptive	Prescriptive Linear Fluorescent Fixture ROB	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-	23.20
PEPCO Prescriptive	Prescriptive Interior LED ROB	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	-	-	-	-	-
PEPCO Prescriptive	Occupancy Sensor	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	-	-	-	-	-
DPL SBDI	SBDI Linear Fluorescent Fixture ROB	-	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-
DPL SBDI	SBDI Interior LED ROB	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	-	-	-	-	-
DPL SBDI	Occupancy Sensor	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	-	-	-	-	-
DPL Prescriptive	Prescriptive Linear Fluorescent Fixture ROB	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-	23.20
DPL Prescriptive	Prescriptive Interior LED ROB	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	-	-	-	-	-
DPL Prescriptive	Occupancy Sensor	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	-	-	-	-	-
SMECO SBDI	SBDI Linear Fluorescent Fixture ROB	-	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-

SMECO SBDI	SBDI Interior LED ROB	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	-	-
SMECO Prescriptive	Prescriptive Linear Fluorescent Fixture ROB	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-	23.20
SMECO Prescriptive	Prescriptive Interior LED ROB	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	-	-	-	-	-
SMECO Prescriptive	Prescriptive Exterior LED ROB	-	30.56	-	30.56	30.56	-	30.56	-	30.56	30.56	-	30.56	30.56	-	-
SMECO Prescriptive	Occupancy Sensor	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	-	-	-	-	-
PE Prescriptive	Prescriptive Linear Fluorescent Fixture ROB	-	-	-	-	23.20	-	-	(30.70)	-	23.20	-	-	-	-	23.20
PE Prescriptive	Prescriptive Interior LED ROB	-	12.44	12.44	-	12.44	12.44	-	12.44	12.44	-	-	-	-	-	-
PE Prescriptive	Prescriptive Exterior LED ROB	-	30.56	-	30.56	30.56	-	30.56	-	30.56	30.56	-	30.56	30.56	-	-
PE Prescriptive	Occupancy Sensor	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	24.03	-	-	-	-	-