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# INCREMENTAL COST STUDY REPORT
# FINAL

**A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets**

**Prepared for the Evaluation, Measurement and Verification Forum**

**Chaired by the Northeast Energy Efficiency Partnerships**


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## *Glossary of Terms*

ACH = Air Changes per hour
AFUE = Annual Fuel Utilization Efficiency
ASHP = Air-source Heat Pump
Btu = British Thermal Unit
CAE = Combined Appliance Efficiency
CFM = Cubic Feet per Minute
DOE = U.S. Department of Energy
ECM = Electronically Commutated Motor
EF = Energy Factor
EMV = Evaluation, Measurement and Verification
HSPF = Heating Seasonal Performance Factor
HVAC = Heating, Ventilation, and Air-Conditioning
ICS = Incremental Cost Study
kBtu/h = Thousand Btus per hour
MBH – Thousands of BTUs per hour
NC = New Construction
NCI = Navigant Consulting, Inc.
NEEP = Northeast Energy Efficiency Partnerships
NRS = Non-Regional Specific costs
PPI = Producer Price Index
QC = Quality Control
RET = Retrofit
ROB = Replace on burnout
R.S. Means – Construction/Market cost estimation company
SEER = Seasonal Energy Efficiency Ratio
SWH = Storage Water Heater
TAG = Technical Assistance Group
TRC = Total Resource Cost Test
TRM = Technical Reference Manual
WH = Water Heater

## *Preface*

### The Regional EM&V Forum

The Regional Evaluation, Measurement and Verification (EM&V) Forum (Forum) is a project managed and facilitated by Northeast Energy Efficiency Partnerships, Inc. (NEEP). The Forum's purpose is to provide a framework for the development and use of common and/or consistent protocols to measure, verify, track, and report energy efficiency and other demand resource savings, costs, and emission impacts to support the role and credibility of these resources in current and emerging energy and environmental policies and markets in the Northeast, New York, and Mid-Atlantic region. Jointly sponsored research is conducted as part of this effort. For more information, see http: www.neep.org/emv-forum.

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**Technical Advisory Group**
Mike Sommer, Berkshire Gas
Dave Larson, National Grid
Dave Jacobson, National Grid
Charles Olsson, NStar
Dave Weber, NStar
Nikola Janjic, Vermont Energy Investment Corp.
Scott Harrington, Vermont Gas
Bryan Henderson, NYSERDA
Debi Drake, Baltimore Gas and Electric
Randy Vagnini, Northeast Utilities

### *Use of the Incremental Cost Study*

The Incremental Cost Study (ICS) team took great pains to carefully establish the costs presented in the ICS and to respond to concerns raised by any party. The study team believes these costs are an accurate portrayal of equipment and labor costs for the project measures as they exist today. However, the costs developed for the Incremental Cost Study are not intended to be mandatory; the study team and the Subcommittee recognize that energy efficiency baselines and efficient measure specifications for energy-efficient equipment may vary among and within the Forum region states, and will certainly change over time.

The ICS, like any cost study, is intended to capture the incremental equipment and labor costs between agreed baselines and a set of common energy efficiency measures, in capacities and efficiencies specified in the study as agreed to by the Research Subcommittee members. The ICS was structured to be more flexible than past incremental cost studies, creating cost curves that can accommodate scaling by capacity and to some extent capturing changes over time. The ICS methodology was designed to make updating these costs a lesser effort than establishing them. The study team has provided the workbooks used to develop costs for each measure. The workbooks are completely open and can be customized to accommodate updated or special circumstance data.

The study team recognizes that the costs contained in any such study are a snapshot of the market taken at a particular moment and not a final answer for all equipment and all applications. These costs were developed in active marketplaces and are subject to fluctuations caused by factors such as demand for products, changes in underlying manufacturing, distribution, and transportation costs, dominance of certain companies in certain equipment markets, increased competition in other product markets, and demand for appropriately skilled labor.

Similarly, measure baselines will change through federal and state regulatory processes and through revised understandings of specific market baselines. Federal standards will set the minimal baseline but a state or market may really have a higher baseline for a variety of reasons, such as new construction practices or customer demand for more efficient equipment than the minimum standard.

Additionally, how efficient equipment is specified may vary among jurisdictions or change over time. In the ICS, Technical Advisors have raised questions about some efficient equipment being bundled with features that add to cost without adding to efficiency. A program administrator or a regulator may determine that it is not appropriate to pay that premium cost, even if bundled with other efficient features, and only consider the costs attributable to the efficiency increase.

The ICS costs are provided to be used by program administrators and others who are planning, implementing and evaluating energy efficiency programs as they see fit. The study team hopes that all concerned find these costs useful to their efforts in the various markets and that these costs and the methods used to determine them play a role across the region.

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# 1. Executive Summary

## *1.1 Introduction*

This report describes the methods and results of the Incremental Cost Study (ICS), commissioned by the Evaluation, Measurement and Verification (EM&V) Forum Research Subcommittee (Subcommittee) to investigate and update incremental costs for a number of common measures employed in energy efficiency programs. The EM&V Forum and the Subcommittee are composed of program administrators and other energy efficiency professionals from among the six New England states, New York, Maryland, Delaware, and the District of Columbia. The Forum is facilitated by staff of the Northeast Energy Efficiency Partnerships (NEEP), and assisted by Subcommittee members and technical staff of the member organizations.

The EM&V Forum states as its overall objective, "to support the successful expansion of demand-side resource policies and programs." Under the overall objective, the Subcommittee undertook the ICS in order to update costs for common energy efficiency measures across the New England and Mid-Atlantic regions. The ICS Request for Proposals stated:" The objectives of the Project are to develop electric and gas efficient measure incremental cost assumptions that will improve the ability of efficiency program planners, program administrators, program evaluators and regulators to:

- Retrospectively assess program cost-effectiveness.
- Prospectively estimate potential program cost-effectiveness to inform which measures and/or programs should be part of efficiency program portfolios.
- Inform program design, particularly financial incentive levels."

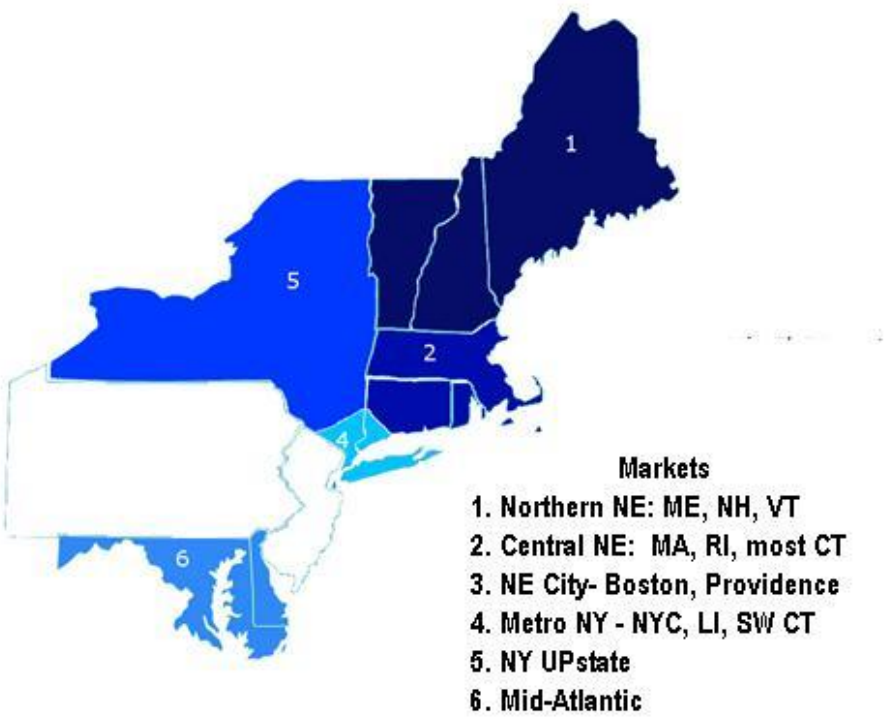
Such studies have typically been difficult and expensive to accomplish. Because of the difficulty and expense, limited evaluation resources, and evaluation research priorities that often focused on other priorities, incremental cost studies have been few and far between over the last decade. Updates of existing studies often pointed to far older studies as their primary sources. However, newer energy efficiency markets such as the Forward Capacity Markets initiated by Independent System Operator-New England and PJM adopted rigorous EM&V guidelines that could call many updates into question because of the data vintage. Further, increased national baseline efficiency standards for several popular energy efficiency measures such as residential central air conditioning and gas boilers and furnaces, added new pressures. Each additional savings increment produces a smaller savings percentage but cost increases are not necessarily in direct proportion to savings; if there is a new technology or manufacturing process involved, the next increment for any measure might be considerable. But cost-effectiveness tests are not sensitive to the sometimes nonlinear relationship between costs and savings, or the observed circumstance that some highly efficient measures are packaged with premium features that add to cost without adding additional energy savings.

The study's overall goal was to determine baseline and efficient measure costs for a series of energy efficiency measures of interest to the Subcommittee and the incremental costs of moving from baseline to

efficient measures. The ICS determined the cost of material/equipment for baseline and efficient measures, the cost of baseline labor and where appropriate incremental costs of labor.

The nine states involved in the ICS covered six markets identified by the project team, from New England, New York, and the Mid-Atlantic. Figure 1-1 shows the six markets identified.

**Figure 1-1: ICS Markets**




**ICS Markets**

| Market | Market Code | Market Territory | Adjustment Factor[1] |
|---|---|---|---|
| Northern New England | 1 | ME, VT, NH | 85.1 |
| Central/Southern New England | 2 | MA , RI, most CT | 105.3 |
| New England City | 3 | Boston, Providence | 111.5 |
| Metro New York | 4 | NYC, metro suburbs Southwest CT | 125.6 |
| Upstate New York | 5 | Albany, Buffalo, Rochester, balance of the state | 98.9 |
| Mid-Atlantic | 6 | MD, DE, DC | 91.5 |
| Non-Regional Specific (NRS) | - | - | 100 |

[1] Adjustment Factor is a cost factor applied to the identified markets to normalize costs collected in each market, and to then determine the costs in each market following analysis of each measure data set. A full explanation is provided in Section 4 of the report.

## *1.2 Project Overall Approach*

Navigant Consulting, Inc. (Navigant) based its project approach on four essential strategies:

- Focus closely on measures receiving incentives in current and recent energy efficiency programs.
- Develop a transparent methodology that would make it clear to the Subcommittee and other audiences how costs were collected and analyzed.
- Develop measure cost curves that are scalable, accommodating a range of measure sizes and capacities, and that can be projected forward to be useful results for plans in later years.
- Work closely with on-the-ground program implementation staff and other program administrator staff who provided real-world feedback and advice.

### 1.2.1 ICS Phase 1: Secondary Research

The ICS design consisted of two phases. In Phase One, Navigant performed secondary research on 18 measures pre-selected by the EM&V Research Subcommittee and designated as first and second priorities by the Subcommittee**.**

The project design called for Navigant to perform two substantial Phase 1 tasks:

- Determine the measure baselines and efficient measure characteristics for each of the 18 initial measures.
- Research available cost data to assess its applicability to current cost needs and/or its usefulness as a base from which updated incremental costs could be developed, and recommend a set of measures that would benefit from additional primary research in Phase Two. Table 1-1 shows the initial project measures selected by the Subcommittee. Six of these measures in gas technologies were pre-selected for primary research; however, Navigant conducted full secondary research on all initial measures.

**Table 1-1: Initial Measures Selected by the Subcommittee for the ICS by Subcommittee Priority**

| Measure # | Measure | Project Application |
|---|---|---|
| | **Top Priority Measures** | |
| 1 | Residential central air conditioners | ROB/NC |
| 2 | Residential air source heat pumps | ROB/NC |
| 3 | Residential furnace fans (e.g., ECM fans) | ROB/NC[2] |
| 4 | Commercial unitary air conditioners | ROB/NC |
| 5 | Residential insulation upgrades (attic, wall, basement) | RET/NC |
| 6 | Residential air sealing | RET/NC |
| 7 | Residential gas furnaces | ROB/NC |
| 8 | Residential gas boilers | ROB/NC |
| 9 | Commercial gas boilers | ROB/NC |
| 10 | Combination heat hot water | ROB/NC |
| 11 | Tankless on-demand water heater | ROB/NC |
| 12 | Indirect water heater | ROB/NC |
| | **Second Priority Measures** | |
| 13 | Large commercial HVAC measures (e.g., chillers) | ROB/NC |
| 14 | Variable frequency drives | RET/NC |
| 15 | Ductless mini-splits air conditioners and heat pumps | ROB/NC |
| 16 | Differential dual enthalpy economizers | ROB/NC |
| 17 | Commercial lighting controls | RET/NC |
| 18 | Energy management systems | RET/ROB/NC |

Measure baselines were determined primarily through review and analysis of existing Technical Reference Manuals (TRMs). Not every TRM agreed on either the baseline or efficient measure characteristics. To resolve any concerns, the project team adopted a consensus approach for each measure and then proposed both baseline and efficient measure characteristics to the Subcommittee for review and comment. The resulting baselines were used throughout the project in Phases 1 and 2.

In the Phase 1 secondary research task, Navigant searched available literature and studies to provide a basis for recommending which of the Subcommittee-selected measures should receive further primary research. The ICS project resources would support Phase 2 primary research on a dozen measures in all; thus, the Phase 1 goal was to winnow the initial list to measures that seemed most appropriate for Phase 2 primary research. To accomplish the Phase 1 goal, Navigant collected and examined more than 30 studies. The study team examined each study along six major parameters and a total of 20 indicators to determine their relevance and utility for the ICS. As indicated in Table 1-2 below, each study was rated and scored on eight quantitative factors. The complete worksheets for all secondary research are provided in the electronic appendices to this report.

[2] ROB or EUL (End of Useful Life) = Replace on Burnout: customer has choice of replacing with standard or efficient equipment.
RET = Retrofit: an efficient measure added to existing facility (insulation) or equipment.
NC = New Construction: builder/buyer has choice of standard or efficient measures.

The study team also considered qualitative factors, such as the Subcommittee's initial priorities, geographic importance (e.g., air source heat pumps are more relevant to Mid-Atlantic States than New England), and customer sector.

**Table 1-2: Secondary Research Quantitative and Qualitative Factors Considered**

| Quantitative Factors | Qualitative Factors |
|---|---|
| Number of Sources | Subcommittee First Priority Measures |
| Data Vintage | Geographic Concerns - Mid-Atlantic, New England |
| Baseline Measure Cost Completeness | Residential vs. Commercial/Industrial |
| Efficient Measure Cost Completeness | Relative Cost-Effectiveness |
| Labor Breakouts Provided | Widgets vs. System Measures |
| Full Costs Provided | Available Budget (number of measures that could be researched) |

The study team's recommendations for primary research were limited by project resources to 12 measures. Without that limitation the ICS team would have recommended that all measures on the initial Subcommittee list be subject to primary research. The team found considerable incompleteness and inconsistency in the existing cost data it reviewed. Some cost data were quite old or were updated estimates based on results from studies conducted a decade ago or longer. Studies sometimes reported material costs only or reported costs without making clear the extent to which labor and materials were included. Baselines in older materials did not always coincide with current baselines, and so on. For these reasons, the project team determined the time and effort required to vet and report the costs found in study data uncovered during the secondary research would not be a good use of project resources.

Table 1-3 shows the measures selected for primary research by the Subcommittee, following Navigant's recommendations. The Subcommittee accepted most of Navigant's recommendations, making the following changes:

- » ECM motors, which were a separate measure in the initial measure grouping, were combined with gas furnaces.
- » Residential insulation was not recommended as a highest priority but was designated by the Subcommittee for primary research.

### 1.2.2 Phase 2: Primary Research

The term primary research is used to define specific measure cost data obtained from the sources providing the measure, such as a retailer, wholesaler, or installing contractor.

The list of primary research measures is shown in Table 1-3.

**Table 1-3: Measures Selected for Primary Research**

| Electric Measures* | Gas Measures |
|---|---|
| Insulation | Residential Gas Furnaces incl. ECMs |
| Air Sealing | Residential Gas Boilers |
| Residential Central Air Conditioning | Commercial Gas Boilers |
| Residential Air Source Heat Pumps | Residential Combination Heat and Hot Water Units |
| Commercial Unitary Air Conditioning | On-Demand Water Heaters |
| Commercial Lighting Controls | Indirect Water Heaters |

* Measures were deemed "Electric" only to distinguish them from the specific gas measures requested by the Gas Networks.

The Phase 2 primary research methodology consisted of direct data collection and analysis through the use of structured telephone interviews conducted by experienced Navigant staff who were knowledgeable about each measure. Navigant was not researching a single efficient measure in most cases but was actually collecting data on a matrix of baseline and efficient measures in multiple sizes and efficiencies.

The ICS was unique in focusing on actual measures, including makes and models currently participating in energy efficiency programs. The project team was able to do this by obtaining extracts of efficiency program databases that detailed equipment actually receiving incentives. The greatest barriers to data collection through interviews proved to be first, variability in accessibility and content of program data bases, and second, seasonal demands on contractors in the prime heating and cooling seasons.

For all ICS measures, installer interviews were the primary data source. Where needed to ensure enough data for a robust analysis at a 90 percent Confidence Interval, Navigant supplemented data from secondary data sources, primarily the California Database for Energy Efficiency Resources (DEER). In some cases, Navigant also obtained supplemental data from Internet sources. This was particularly the case for commercial lighting controls, which are essentially a commodity item (and come in a great variety of configurations).

Navigant collected both measure material/equipment and labor costs to provide complete costs and where necessary for program administrators to allow materials and labor costs to be separated for the purposes of program planning and evaluation. Data were primarily collected under Replace on Burnout (ROB) and Retrofit (RET) scenarios. In Replace on Burnout[3], the costs considered are the incremental materials/equipment cost between the standard replacement and the specified energy-efficient measure. Labor costs are considered in this scenario only to the extent there is some labor that might not be needed for the standard measure, as in the labor required to install a direct vent for a high-efficiency furnace. In Retrofit, the full costs of materials and labor are considered. Some data were collected for

[3] In some jurisdictions, End of Useful Life allows replacement of appliances and equipment that operate but are inefficient and well past their expected lifetimes. R.O.B. costs reported here also apply to EUL approaches.

New Construction (NC) but NC scenarios were not fleshed out for cases in which credits could be applied.[4]

The data collected were the actual measure costs that would be charged by the installer for a particular measure of a particular size/capacity and efficiency. Labor costs were established by ascertaining the number of man-hours required for the installation in the appropriate scenario (incremental or full labor costs) and then determining the labor rates charged, generally using a single labor rate per installer.

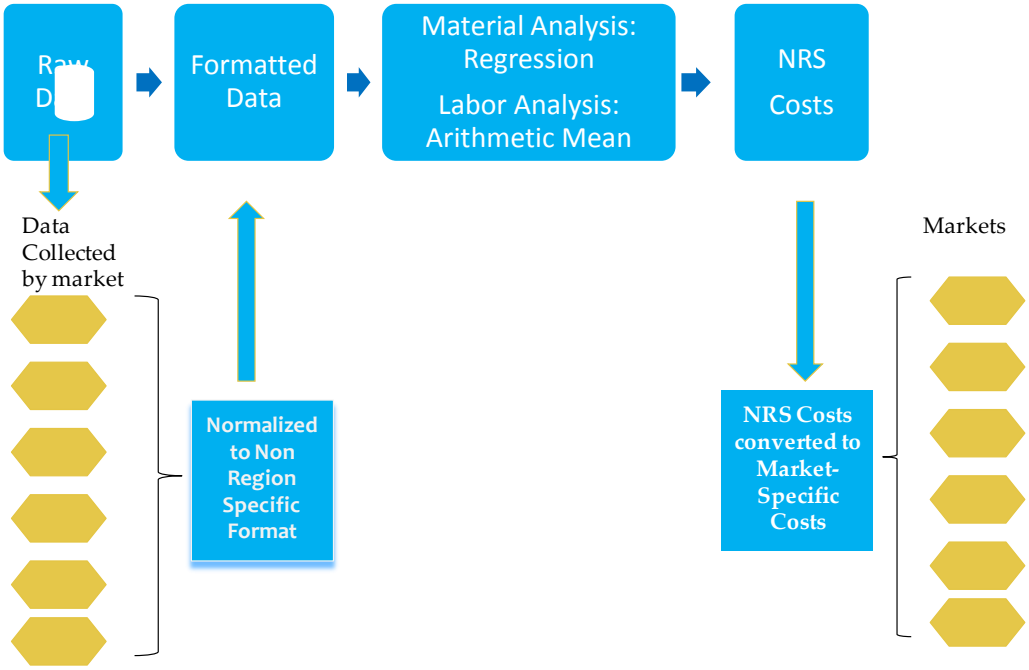
Navigant attempted to collect data from across the study region for each measure, relying on program administrator databases to provide make and model equipment costs and names and contact information for all installers. Interviews for each market were allocated on a rough proportional basis to ensure that all markets were represented; smaller markets such as Northern New England were allocated slightly more interviews to provide a reasonable sample. However, not all study measures were offered by all program administrators. Further, the availability and specificity of available data, generally collected and held by program implementation contractors, varied greatly. As a result, some measure data were collected more in one region than another, as shown in Section 4 of the report.

In order to prepare collected data for analysis, Navigant normalized the cost data to provide a single analysis platform for each measure. Using the market factors described in Section 1, all cost data were normalized into Non-Region Specific (NRS) formats. For example, cost data on gas furnaces collected from Vermont in Northern New England were divided by the Northern New England, Market 1, cost factor 0.85; data on gas furnaces collected from Massachusetts in Central/Southern New England, Market 2, were divided by 1.05, normalizing the VT and MA data to the Non-Regional Specific data platform. The data were then analyzed as a single data set, producing the NRS value for the measure. The NRS value was then multiplied by the appropriate factor for each market and reported in the report tables.

Figure 1-2 describes the process graphically.

[4] For example, a well-insulated and air-sealed new home might require a smaller heating system than one only insulated to code; or if the design minimized a venting cost a cost credit could be taken. Most of that credit would likely be taken at the program level. Navigant did not fully investigate this sort of credit within the ICS scope.

**Figure 1-2: Cost Analysis Process Including Formatting, Non-Regional Specific (NRS) Cost Development and Final Cost Determination for Each Market**




Technical advisors to the Subcommittee then vetted the resultant costs. The advisors were primarily program administrator technical/program implementation staff who were well informed about each measure.

Section 5 of this report contains a full explanation of the overall analysis process and all factors used. Section 6 contains analysis detail for each project measure.

## *1.3 Non-Regional Specific Costs*

The 12 tables in this section, Table 1-4 through Table 1-15, show the NRS and market-specific costs for each ICS measure. The NRS costs are the common data platform for the study. Raw data collected from the various market areas were normalized to the NRS format so that all data were analyzed on a common base. The completed analysis was, therefore, in NRS form as in the Table 1-4 through Table 1-12 below. Those tables include material/equipment cost, total cost, and the labor cost, which is noted in "Notes" at the bottom of each table. To obtain the measure costs for any given market, the NRS costs are multiplied by the appropriate factor shown in Figure 1-1 above. All of the data for the costs tables are also found in the electronic workbooks accompanying the report.

### Table 1-4: Residential Furnace Incremental Cost Results ($/unit) – Non-Regional Specific

| Size (kBtu/h) | 90 AFUE | | 92 AFUE | | 94 AFUE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 60 | $828 | $1,131 | $982 | $1,284 | $1,136 | $1,438 |
| 70 | $838 | $1,140 | $992 | $1,294 | $1,146 | $1,448 |
| 80 | $848 | $1,150 | $1,002 | $1,304 | $1,156 | $1,458 |
| 90 | $858 | $1,160 | $1,012 | $1,314 | $1,165 | $1,468 |
| 100 | $868 | $1,170 | $1,021 | $1,324 | $1,175 | $1,478 |
| 120 | $887 | $1,190 | $1,041 | $1,343 | $1,195 | $1,497 |

Notes:
Baseline = 80% AFUE furnace
Total Installed Cost = Material Cost + $306 Labor

### Table 1-5: Residential Boiler Incremental Cost Results ($/unit) – Non-Regional Specific

| Size (kBtu/h) | 85 AFUE | | 90 AFUE | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 50 | $501 | $501 | $1,260 | $2,142 |
| 75 | $630 | $630 | $1,388 | $2,271 |
| 105 | $784 | $784 | $1,542 | $2,425 |
| 125 | $886 | $886 | $1,645 | $2,528 |
| 150 | $1,015 | $1,015 | $1,773 | $2,656 |
| 175 | $1,143 | $1,143 | $1,902 | $2,785 |
| 200 | $1,272 | $1,272 | $2,030 | $2,913 |
| 225 | $1,400 | $1,400 | $2,159 | $3,041 |
| 250 | $1,529 | $1,529 | $2,287 | $3,170 |
| 300 | $1,785 | $1,785 | $2,544 | $3,427 |

Notes:
All costs are *incremental*; Baseline = 80% AFUE Boiler.
Total Installed Cost = Material Cost + Labor Cost (Labor = $0 for 85 AFUE efficiency level; Labor = $893 for the 90 AFUE efficiency level)

**Table 1-6: Commercial Boiler Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (kBtu/h) | 85 Thermal Efficiency | | 90 Thermal Efficiency | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 300 | $625 | $625 | $2,691 | $3,305 |
| 500 | $1,385 | $1,385 | $3,450 | $4,064 |
| 700 | $2,144 | $2,144 | $4,210 | $4,823 |
| 900 | $2,903 | $2,903 | $4,969 | $5,582 |
| 1100 | $3,662 | $3,662 | $5,728 | $6,342 |
| 1300 | $4,421 | $4,421 | $6,487 | $7,101 |
| 1500 | $5,181 | $5,181 | $7,246 | $7,860 |
| 1700 | $5,940 | $5,940 | $8,006 | $8,619 |
| 2000 | $7,079 | $7,079 | $9,145 | $9,758 |
| 2200 | $7,838 | $7,838 | $9,904 | $10,517 |

Notes:
Baseline = 80% Thermal Efficiency ($E_T$) Boiler
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for 85 $E_T$ efficiency level; Incremental Labor = $614 for the 90 $E_T$ efficiency level)

**Table 1-7: Residential Tankless Water Heater Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (kBtu/h) | Storage WH Equivalent Size (Gal) | 82 EF | | 94 EF | |
|---|---|---|---|---|---|
| | | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 180 | 30 | $1,334 | $1,727 | $1,786 | $2,290 |
| 180 | 40 | $1,247 | $1,640 | $1,699 | $2,203 |
| 180 | 48 | $1,177 | $1,571 | $1,630 | $2,134 |
| 199 | 50 | $1,249 | $1,643 | $1,702 | $2,206 |
| 199 | 65 | $1,119 | $1,512 | $1,571 | $2,075 |

Notes:
Baseline = 40-gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $394 for 82 EF efficiency level; Incremental Labor = $504 for the 94 EF efficiency level)

### Table 1-8: Residential Indirect Water Heater Incremental Cost Results ($/unit) – Non-Regional Specific

| Size (kBtu/h) | 40 kBtu/h | | 60 kBtu/h | | 80 kBtu/h | | 120 kBtu/h | |
|---|---|---|---|---|---|---|---|---|
| Storage WH Size (Gal) | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 30 | $846 | $1,089 | $1,208 | $1,451 | $1,529 | $1,772 | $2,093 | $2,336 |
| 40 | $759 | $1,002 | $1,121 | $1,364 | $1,442 | $1,685 | $2,007 | $2,249 |
| 48 | $690 | $933 | $1,051 | $1,294 | $1,372 | $1,615 | $1,937 | $2,180 |
| 50 | $672 | $915 | $1,034 | $1,277 | $1,355 | $1,598 | $1,920 | $2,162 |
| 65 | $542 | $785 | $903 | $1,146 | $1,225 | $1,467 | $1,789 | $2,032 |

Notes:
Baseline = 40-gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $243 for all indirect water heater sizes)

### Table 1-9: Residential Combination Heat/Hot Water Incremental Cost Results ($/unit) – Non-Regional Specific

| Size (kBtu/h) | 90 CAE | | 93 CAE | | 95 CAE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 110 | $158 | $1,073 | $1,189 | $2,104 | $1,877 | $2,791 |
| 120 | $78 | $993 | $1,109 | $2,024 | $1,797 | $2,711 |
| 126 | $30 | $945 | $1,061 | $1,976 | $1,749 | $2,663 |
| 150 | -$162 | $753 | $869 | $1,784 | $1,557 | $2,471 |
| 199 | -$554 | $360 | $477 | $1,392 | $1,165 | $2,079 |
| 110 | $158 | $1,073 | $1,189 | $2,104 | $1,877 | $2,791 |

Notes:
Baseline = 80 AFUE hot water gas boiler
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $914 for all efficiency levels)

### Table 1-10: Residential Insulation Incremental Cost Results ($/ft2) – Non-Regional Specific

| Insulation Type | | Material Cost (averages all insulation types) | Total Installed Cost |
|---|---|---|---|
| **Attic** | **R-19** | $1.25 | $2.02* |
| | **R-38** | $1.92 | $2.69 |
| | **R-60** | $2.70 | $3.47 |
| **Wall** | **R-13** | $0.83 | $1.56 |
| | **R-19** | $1.24 | $2.02 |
| | **R-21** | $1.37 | $2.17 |
| **Basement** | **Wall (R-16)** | $1.34 | $2.93 |
| | **Rim Joist (R-17)** | $1.85 | $5.97 |

Notes:
Baseline = No Insulation
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $077/sq. ft for Attic insulation; Incremental Labor = $0.68/sq. ft for Wall insulation; Incremental Labor = $1.58/sq. ft for Basement Wall insulation; Incremental Labor = $3.20/sq. ft for Basement Rim Joist insulation)
*Open blow cellulose only Labor =$0. .36 /sq ft. Total (installed cost R19=$1.67, R38=$2.04, R60=$2.48)

### Table 1-11: Residential Air-Sealing Incremental Cost Results – Non-Regional Specific

| | Incremental Cost for 0.35 ACH | | |
|---|---|---|---|
| | **Material Cost** | **Labor Cost** | **Total Installed Cost** |
| Total Cost/ SF ($) | $0.09 | $0.36 | $0.45 |
| Total Cost/ CFM ($) | $0.25 | $0.97 | $1.21 |

Notes:
Baseline = 0.5 ACH
Total Installed Cost = Material + Labor; All costs are *incremental.*

### Table 1-12: Residential Central Air Conditioner (AC) Incremental Cost Results ($/unit) – Non-Regional Specific

| Size (tons) | 14.5 SEER | | 15 SEER | | 16+ SEER | |
|---|---|---|---|---|---|---|
| | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** |
| | $923 | $923 | $1,164 | $1,164 | $2,367 | $2,367 |
| 3 | $1,104 | $1,104 | $1,345 | $1,345 | $2,548 | $2,548 |
| 4 | $1,285 | $1,285 | $1,526 | $1,526 | $2,729 | $2,729 |
| 5 | $1,466 | $1,466 | $1,707 | $1,707 | $2,910 | $2,910 |

Notes:
Baseline = 13 SEER
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

**Table 1-13: Residential ASHP Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (tons) | 14.5 SEER | | 15 SEER | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $993 | $993 | $1,128 | $1,128 |
| 3 | $1,335 | $1,335 | $1,470 | $1,470 |
| 4 | $1,677 | $1,677 | $1,812 | $1,812 |
| 5 | $2,019 | $2,019 | $2,154 | $2,154 |

Notes:
Baseline = 13 SEER / 7.7 HSPF
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

**Table 1-14: Commercial Lighting Controls Incremental Cost Results ($/unit) – Non-Regional Specific**

| Control Type | Material Cost | Labor Cost | Total Installed Cost |
|---|---|---|---|
| Fixed Photocontrol | $29 | $76 | $105 |
| Turn-Lock Photocontrol | $13 | $115 | $128 |
| Wired-in Photocontrol | $33 | $67 | $100 |
| Screw-in Photocontrol | $32 | $76 | $108 |
| Swivel Photocontrol | $38 | $76 | $114 |
| Button Photocontrol | $27 | $76 | $103 |
| Shorting Cap Photocontrol | $14 | $96 | $110 |
| Electronic Timer | $199 | $191 | $390 |
| Digital Timer | $97 | $159 | $256 |
| Switch Timer | $268 | $229 | $497 |
| Passive Infrared Occ. Sensor - Ceiling | $102 | $138 | $239 |
| Passive Infrared Occ. Sensor - Wall | $51 | $57 | $108 |
| Passive Infrared and Ultrasonic Occ. Sensor - Ceiling | $153 | $76 | $230 |
| Passive Infrared and Ultrasonic Occ. Sensor - Wall | $110 | $51 | $162 |

Notes:
Baseline = No Lighting Controls
Total Installed Cost = Material + Labor; All costs are *incremental.*

**Table 1-15: Commercial Unitary AC Incremental Cost Results ($/ton) – Non-Regional Specific**

| Size (tons) | CEE Tier 1 (11.5 EER) | | CEE Tier 2 (12 EER) | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 5.4 | $123 | $123 | $174 | $174 |
| 11.3 | $184 | $184 | $235 | $235 |
| 20.0 | $102 | $102 | $138 | $138 |

Notes:
Baseline = 10.3 EER for capacities of 65-135 tons; 9.7 EER for capacities of 135-240 tons.
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

## *1.4 Key Findings and Recommendations*

### 1.4.1 Project Summary

The ICS developed incremental costs for 12 primary energy efficiency measures in a variety of measure sizes/capacities and efficiencies appropriate to each measure. The ICS captured both materials/equipment and labor costs, normalized them through a transparent[5] analysis process that produced NRS costs for each measure, and then using cost factors obtained from R.S. Means adjusted costs for each of six markets representing participating NEEP states and program administrators. This process provided incremental costs across these states and markets achieving economies of scale not typically achievable in incremental cost studies.

The ICS developed cost curves for each measure. For many measures these costs are scalable, so they can capture differences among measure sizes or capacities in current programs. The cost curves can also be readily extended through successive years in most cases, with supplemental interviewing to assess changes in the specific equipment. Further, program planners and other users can customize the spreadsheets to incorporate their own data such as state or local cost factors, conduct sensitivity analyses, or make other customizations to accommodate their particular needs.

### 1.4.2 Premium Measure Costs

Navigant encountered a situation that affects several types of efficient equipment and appliances, including Residential Air Conditioning and possibly Air Source Heat Pumps among the study measures. Briefly, some energy-efficient appliances and equipment are manufactured and sold as premium products. Along with higher efficiencies, such equipment may have more user-friendly or flexible controls, better warranties, and other features that may affect convenience, utility or appearance but add little or nothing to increased energy efficiency.

The premium product circumstance was clearest for Residential Air Conditioning. The baseline efficiency for this measure is Seasonal Energy Efficiency Ratio (SEER) 13. Higher efficiency models are

[5] Navigant's analysis process is transparent in that all inputs, calculations, and results are provided to the Subcommittee in an open environment. There are no inaccessible "black box" calculations.

offered with additional features that increase cost but don't add to the unit's energy efficiency; generally these premium models are the only models offered by installers who participate in the energy efficiency programs. There are some "vanilla"[6] SEER 15 units in the market but these models are mainly lower end brands. The lack of "vanilla" units could be attributable to any of several factors or a combination of factors, such as manufacturer/distributor supply requirements, installer margins(premium products typically offer more profit), installers of "vanilla" units willingness to adhere to program administrator sizing and/or quality installation requirements, perceived reliability of low-end brands, and other factors to be determined. There is almost certainly a cost premium to the SEER 15 units currently receiving incentives for the non-energy efficiency features. That cost premium is bundled into the total unit cost in ways that are not transparent. However, one commenter thought that unbundling the premium costs should not be considered because consumers would be more likely to buy units with the premium features.

Energy efficiency programs are potentially affected by premium product in the following way. As standards increase, the incremental savings achievable between the baseline and the efficient increment decrease. If more efficient equipment is available only in premium products, with the smaller savings increment, the total cost per increment of savings may increase.

### 1.4.3 Measures Not Selected for Primary Research

Navigant believes that given the available existing cost data, all of the original program measure costs that were not selected for primary research would benefit from further cost research. The ICS was designed to provide robust costs for measures that would be most valuable and cost effective to research and report. Considerations of time and budget limited the number of measures for which the ICS project performed primary research. The secondary research process was therefore a winnowing process. Navigant's charge for Phase 1 was discovery and assessment of existing data rather than cost analysis. The assessment raised many concerns about the quality, consistency, timeliness, and overall applicability of the existing cost data. Age was the largest single consideration and we note in that regard that the Forward Capacity Markets have adopted strict standards on study vintage. Further, inconsistent presentations of measures, materials, and/or labor and other factors made it difficult to discern which studies could be considered directly comparable. For these reasons, Navigant did not provide costs in its secondary research report. The study team was concerned that doing so could be seen as an endorsement of the costs found in that phase.

Future cost work characterizing some measures that operate essentially as systems will pose challenges, mainly with respect to establishing relevant scenarios for measures that can be applied in greatly varying situations. However, with careful specification even more complex measures can be systematically estimated. Navigant believes this work is still needed.

[6] "Vanilla" means products that meet a specific energy efficiency standard without additional features that may enhance convenience or appearance, adding additional cost without adding additional energy efficiency.

### 1.4.4 The Importance of Technical Advisory Groups

The ICS required considerable technical expertise on the part of the research team. The study also required frequent input from on-the-ground program administrator staff and other technical experts working for Subcommittee members to ensure that measures were appropriately specified, that baselines were appropriate to the efficient measures, that the interview protocols asked the correct questions, and that the cost results squared with reality. NEEP assisted the study by recruiting and organizing technical advisors and actively seeking their input at each project stage. The advisors provided advice, and questioned some assumptions, some equipment specifications, and some results in open exchanges that were critically helpful to obtaining and ensuring robust project results.

### 1.4.5 The Importance of Project Data

Navigant's project approach focused on the specific equipment makes and models receiving incentives in current and recent program administrator programs. Obtaining such information was a significant challenge. The project team learned that most program administrators did not themselves maintain data at the necessary level of detail for this study's purposes in their own databases. In most cases, the level of data detail needed for this study was held by program implementation contractors; even among implementers, the breadth and depth of measure and installer data varied greatly. Navigant considered an alternate approach of examining actual incentive invoices, which has been done in other studies; however, this approach was not practical among the variety of program administrators for conformance with privacy laws and other considerations.

Navigant suggests that program administrators move toward a common approach to data collected and/or extracted as a means to provide reliable data for future cost and other studies. Changing existing databases to accommodate particular needs would be formidable and expensive for program administrators and for implementation contractors. However, it may be possible to develop a common set of data extract standards to pull specific data out of implementation contractor records for needs such as updated incremental costs.

### 1.4.6 Future Joint Efforts Can Facilitate More Frequent Economical Cost Updates

Navigant and others have noted the difficulty and expense of conducting incremental cost studies and the resultant lack of good cost data at a time in which cost side of benefit/cost analysis is becoming more important. This study has been successful for developing costs for a group of measures across a substantial set of markets. However, if this study is an isolated effort, not followed up with some regularity, in a few years program administrators will need almost to start all over again. Navigant suggests some long-term strategies to regularize the cost update process while continuing to take advantage of economies of scale realized for the ICS:

:

1. Decide upon a regular cost update schedule, possibly every three to five years.
2. Concentrate research on measures that provide large percentages of portfolio program savings and where cost sensitivity is relatively high – that is B/C ratios are at the lower end of the spectrum.
3. Consider developing protocols for collecting invoice data that deal with privacy concerns and also provide a common data template.

4. Consider developing panels of distributors and installers who can be regularly polled on costs for participating measures, and structure the panels to minimize gaming, through common data requests, secret shopping, and/or other cross-checking mechanisms.

This list is certainly not exhaustive; however, Navigant hopes it will provide a context for continued effective work in this area.

# 2. Introduction

## 2.1 Project Description

This report describes the methods and results of the Incremental Cost Study (ICS), commissioned by the Evaluation, Measurement and Verification (EM&V) Forum Research Subcommittee (Subcommittee) to investigate and update incremental costs for a number of common measures employed in energy efficiency programs. The EM&V Forum and the Subcommittee are composed of program administrators and other energy efficiency professionals from among the six New England states, New York, Maryland, Delaware, and the District of Columbia. The Forum is facilitated by staff of the Northeast Energy Efficiency Partnerships (NEEP), and assisted by Subcommittee members and technical staff of the member organizations.

The EM&V Forum states as its overall objective, "to support the successful expansion of demand-side resource policies and programs." Under the overall objective, the Subcommittee undertook the ICS in order to update costs for common energy efficiency measures across the New England and Mid-Atlantic regions. The ICS Request for Proposals stated: "The objectives of the Project are to develop electric and gas efficient measure incremental cost assumptions that will improve the ability of efficiency program planners, program administrators, program evaluators and regulators to:

- Retrospectively assess program cost-effectiveness.
- Prospectively estimate potential program cost-effectiveness to inform which measures and/or programs should be part of efficiency program portfolios.
- Inform program design, particularly financial incentive levels."

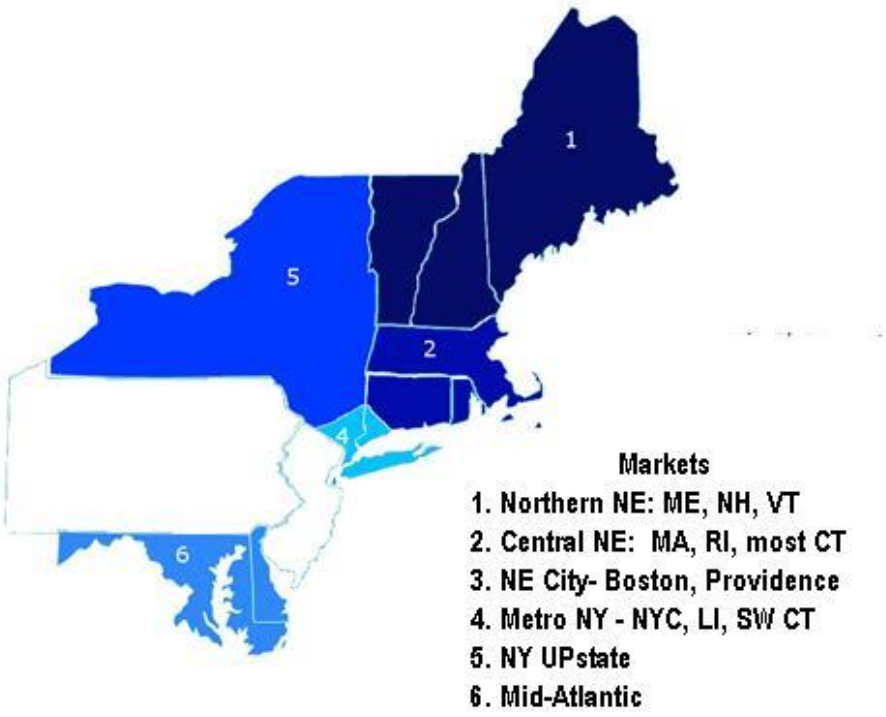
Such studies have typically been difficult and expensive to accomplish. Because of the difficulty and expense, limited evaluation resources, and evaluation research priorities that often focused on other priorities, incremental cost studies have been few and far between over the last decade. Updates of existing studies often pointed to far older studies as their primary sources. However, newer energy efficiency markets such as the Forward Capacity Markets initiated by Independent System Operator-New England and PJM adopted rigorous EM&V guidelines that could call many updates into question because of the data vintage. Further, increased national baseline efficiency standards for several popular energy efficiency measures such as residential central air conditioning and gas boilers and furnaces, added new pressures. Each additional savings increment produces a smaller savings percentage but cost increases are not necessarily in direct proportion to savings; if there is a new technology or manufacturing process involved, the next increment for any measure might be considerable. But cost effectiveness tests are not sensitive to the sometimes nonlinear relationship between costs and savings, or the observed circumstance that some highly efficient measures are packaged with premium features that add to cost without adding additional energy savings.

The study's overall goal was to determine baseline and efficient measure costs for a series of energy efficiency measures of interest to the Subcommittee and the incremental costs of moving from baseline to

efficient measures. The ICS determined the cost of material/equipment for baseline and efficient measures, the cost of baseline labor, and where appropriate incremental costs of labor.

The nine states involved in the ICS covered six markets identified by the project team, from New England, New York, and the Mid-Atlantic. Figure 2-1 shows the six markets identified and the adjustment factors used for each market. The application of these factors is explained in Section 4.

**Figure 2-1: ICS Markets**




**ICS Markets**

| Market | Market Code | Sample Cities | Average Adjustment Factor |
|---|---|---|---|
| Northern New England | 1 | ME, VT, NH | 85.1 |
| Central/Southern New England | 2 | MA , RI, most CT | 105.3 |
| New England City | 3 | Boston, Providence | 111.5 |
| Metro New York | 4 | NYC, metro suburbs Southwest CT | 125.6 |
| Upstate New York | 5 | Albany, Buffalo, Rochester, balance of the state | 98.9 |
| Mid-Atlantic | 6 | MD, DE, DC | 91.5 |
| Non-Regional Specific | - | - | 100 |

## 2.2 *Project Overall Approach*

Navigant Consulting, Inc. (Navigant) based its project approach on four essential strategies:

- Focus closely on measures receiving incentives in current and recent energy efficiency programs.
- Develop a transparent methodology that would make it clear to the Subcommittee and other audiences how costs were collected and analyzed.
- Develop measure cost curves that are scalable, accommodating a range of measure sizes and capacities, and that can be projected forward to be useful results for plans in later years.
- Work closely with on-the-ground program implementation staff and other program administrator staff who provided real-world feedback and advice.

These strategies were designed to provide the Subcommittee with results that are applicable to the broad range of programs, program administrators, and future programs that involve the ICS measures.

## 2.3 *Measure Selection*

Before beginning the study, the Subcommittee considered and prioritized a dozen residential and commercial energy efficiency measures, as shown in Table 2-1. The Subcommittee soon increased the initial measure list to 18 measures. Gas Networks, which cooperatively operates gas energy programs throughout Massachusetts, proposed these additional measures because it needed updated costs for programs to be revised later in 2011. The Subcommittee adopted those measures and agreed that all six gas measures would receive primary research.

**Table 2-1: Initial Measures Selected by the Subcommittee for the ICS by Subcommittee Priority**

| Measure # | Measure | Project Application |
|---|---|---|
| | **Top Priority Measures** | |
| 1 | Residential central air conditioners | ROB/NC |
| 2 | Residential air source heat pumps | ROB/NC |
| 3 | Residential furnace fans (e.g., ECM fans) | ROB/NC |
| 4 | Commercial unitary air conditioners | ROB/NC |
| 5 | Residential insulation upgrades (attic, wall, basement) | RET/NC |
| 6 | Residential air sealing | RET/NC |
| 7 | Residential gas furnaces | ROB/NC |
| 8 | Residential gas boilers | ROB/NC |
| 9 | Commercial gas boilers | ROB/NC |
| 10 | Combination heat hot water | ROB/NC |
| 11 | Tankless on-demand water heater | ROB/NC |
| 12 | Indirect water heater | ROB/NC |
| | **Second Priority Measures** | |
| 13 | Large commercial HVAC measures (e.g., chillers) | ROB/NC |
| 14 | Variable frequency drives | RET/NC |
| 15 | Ductless mini-splits air conditioners and heat pumps | ROB/NC |
| 16 | Differential dual enthalpy economizers | ROB/NC |
| 17 | Commercial lighting controls | RET/NC |
| 18 | Energy management systems | RET/ROB/NC |

There were two project phases:

1. Phase One assessed the state of existing incremental cost studies through secondary research, which involved collecting, reviewing, and assessing applicable incremental cost studies throughout the region and across the country. A total of 30 studies were reviewed in this phase. In addition, Navigant defined measure baselines in this phase to ensure that the project team and the Subcommittee were in accord; not every program administrator used the same baselines or efficient measure specifications, a situation we expect will continue to be true in the future.

2. Phase Two consisted of primary research on 12 of the project measures, upon Navigant's recommendations and the Subcommittee's final measure selection.

The report describes these activities in detail in the sections below:

» Section 3 describes secondary research methodology and results.

» Section 4describes primary research and provides detailed measure cost tables.

» Section 5 contains the detailed measure tables for each project measure.

# 3. ICS Phase 1: Secondary Research

The ICS design consisted of two phases. In Phase 1, Navigant performed secondary research on 18 measures pre-selected by the EM&V Research Subcommittee and designated as first and second priorities by the Subcommittee.

The project design called for Navigant to perform two substantial Phase 1tasks:

» Determine the measure baselines and efficient measure characteristics for each of the 18 initial measures.

» Research available cost data to assess its usefulness and recommend a set of measures that would benefit from additional primary research in Phase 2. **Error! Reference source not found.** above shows the initial project measures selected by the Subcommittee. Six of these measures, in gas technologies, were pre-selected for primary research; however, Navigant conducted full secondary research on all initial measures.

## *3.1 Measure Baselines*

### 3.1.1 Measure Baselines and Efficient Measure Characteristics

In order to provide the Subcommittee with incremental measure costs, it was first necessary to determine the measure baselines for each project measure. Most measures have multiple sizes and efficiencies, and may have differing feature sets as well. Therefore, Navigant was not researching a single efficient measure in most cases but was actually collecting data on a matrix of baseline sizes and multiple sizes and efficiencies of efficient equipment. The project team determined measure baselines primarily through review and analysis of existing TRMs. Not every TRM agreed on either the baseline or efficient measure characteristics.

To resolve any concerns, the project team adopted a consensus approach for each measure and then proposed both baseline and efficient measure characteristics to the Subcommittee for review and comment. A baseline document was presented to the Subcommittee for comment November 18, 2010. The resulting baselines were used throughout the project in Phases 1 and 2. Table 3-1 and Table 3-2 show the measure baseline summary worksheet for the entire original project measure set. The full baseline workbook is appended to the report in electronic form with other ICS workbooks.
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## Table 3-1: Summary Baselines for Initial Project Measures

| Measure | Size | Recommended Study Baseline | Comments |
|---|---|---|---|
| Residential Combination Heat Hot Water | All applications | 80 AFUE boiler and 0.594 EF water heater | |
| Residential Hot Water Tankless | | 0.575 | The baseline efficiency case is a stand alone tank water heater with an energy factor (EF) |
| Residential On Demand Hot water | | 0.575 | The baseline efficiency case is a stand alone tank water heater with an energy factor (EF) |
| Optional Condensing On Demand Hot Water | | | |
| Residential central air conditioners | | 13/11 | SEER/EER |
| Residential air source heat pumps | | 13/11/7.7 | SEER/EER/HSPF |
| Residential gas furnaces | | 78% AFUE | |
| Residential furnace fans (e.g. ECM fans) | | Federal minimum standard permanent split capacity (PSC) furnace fan motor | |
| Residential gas boilers | | 80% AFUE | |
| Commercial unitary air conditioners | <65,000 | 13 | SEER or CEE Tier II Minimum Efficiency |
| Commercial unitary air conditioners | >=65,000 <135,000 | 10.1 | SEER or CEE Tier II Minimum Efficiency |
| Commercial unitary air conditioners | >=135,000 <240,000 | 9.3 | SEER or CEE Tier II Minimum Efficiency |
| Commercial unitary air conditioners | >=240,000 <375,000 | 9 | SEER or CEE Tier II Minimum Efficiency |
| Commercial unitary air conditioners | >=375,000 <760,000 | 9 | SEER or CEE Tier II Minimum Efficiency |
| Commercial unitary air conditioners | >=760,000 | 9 | SEER or CEE Tier II Minimum Efficiency |
| Commercial gas boilers: Hot Water | <300,000 Btuh | 80 AFUE | |
| Commercial gas boilers: Steam | <300,000 Btuh | 75 AFUE | |
| Commercial gas boilers: Hot Water and Steam | >=300,000 and <=2,500,000 Btuh | 75% thermal efficiency/80% combustion efficiency | |
| Commercial gas boilers: Hot Water and Steam | >2,500,000 Btuh | 80% combustion efficiency | |
| Residential insulation upgrades (attic) | | R-19 (Retrofit); R-38 (NC) | |
| Residential insulation upgrades (wall) | | R-11 (Retrofit); R-19 (NC) | |
| Residential insulation upgrades (basement) | | Uninsulated (Retrofit/NC) | |
| Residential air sealing | | 0.5 Air changes per hour | |

| Measure | Size | Recommended Study Baseline | Comments |
|---|---|---|---|
| Large commercial HVAC measures (e.g. chillers): | | | |
| Chiller, Water-Cooled Centrifugal | <150 tons | 0.67 kW/ton (IPLV)/4.72 COP (partial load) | Average |
| Chiller, Water-Cooled Centrifugal | >=150 and <300 tons | 0.61 kW/ton (IPLV)/5.46 COP (partial load) | Average |
| Chiller, Water-Cooled Centrifugal | >=300 tons | 0.56 kW/ton (IPLV)/5.95 COP (partial load) | Average |
| Chiller, Water-Cooled Reciprocating | All applications | 0.696 kW/ton (IPLV)/4.53 COP (partial load) | IPLV from 1 point, average COP |
| Chiller, Water-Cooled Screw and Scroll | <150 tons | 0.677 kW/ton (IPLV)/4.53 COP (partial load) | Average |
| Chiller, Water-Cooled Screw and Scroll | >=150 and <300 tons | 0.632 kW/ton (IPLV)/5.02 COP (partial load) | Average |
| Chiller, Water-Cooled Screw and Scroll | >=300 tons | 0.579 kW/ton (IPLV)/5.68 COP (partial load) | Average |
| Chiller, Air-Cooled | All applications | 10.41 EER (IPLV)/3.05 COP (partial load) | Average EER, COP from 1 point |
| Chiller, Air-Cooled | <150 tons | 1.256 kW/ton (IPLV) | IPLV from 1 point |
| Chiller, Air-Cooled with Condenser | All applications | 1.153 kW/ton (IPLV) | IPLV from 1 point |
| Chiller, Air-Cooled with Condenser | <150 tons | 2.8 COP (partial load) | Average |
| Chiller, Air-Cooled with Condenser | >150 tons | 2.5 COP (partial load) | Average |
| Chiller, Air-Cooled without Condenser | All applications | 1.019 kW/ton (IPLV)/3.1 COP (partial load) | Data from 1 point |
| Cooling Tower, Close Approach | All applications | Standard tower with 10 degree temperature approach | Data from 1 point |
| Gas Chiller | <150 tons | 0.703 kW/ton (IPLV) | Data from 1 point |
| Gas Chiller | >=150 and <300 tons | 0.643 kW/ton (IPLV) | Data from 1 point |
| Gas Chiller | >=300 tons | 0.577 kW/ton (IPLV) | Data from 1 point |
| Variable Frequency Drives | | No controller in place | |
| Ductless mini-splits air conditioners and heat pumps | | 13 SEER, 7.7 HSPF | |
| Differential Dual Enthalpy Economizer | All applications or unspecified | Fixed outside air dry-bulb economizer | |
| Differential Dual Enthalpy Economizer | <5.4 tons | Fixed outside air damper | |
| Differential Dual Enthalpy Economizer | >5.4 tons | Fixed outside air dry-bulb economizer | |
| Energy management systems | | No system in place | |
| Commercial lighting controls | | No controls installed | |

## 3.2 *Literature Search and Assessment*

In Phase 1 research, Navigant consulted a variety of sources and sought the cooperation of Subcommittee members and their respective organizations' staff to recommend and/or provide recent measure cost studies. Navigant also obtained the most recent TRMs for the NEEP member organizations and consulted TRMs in other states as well. A source bibliography is found in Appendix A and is also included in the electronic workbook submitted to NEEP as part of the secondary research results. TRMs are not entirely new but their widespread adoption is recent and there is as yet no standard format, particularly with respect to cost data; TRMs typically focus on measure baselines, efficient equipment choices, and the algorithms. Thus, the availability and usability of cost data varied greatly. Overall, Navigant reviewed 30 studies.

Navigant devised a quantitative scoring formula and rated each of the 18 measures, including the six gas measures that were preselected for primary research. This analysis was recorded in an electronic workbook, which contained the following elements:

- A top-level scoring matrix, showing the components and combined scores for each measure. A table of estimated cost-effectiveness was included but was not taken into account in calculating the total measure score.
- A tab for each study measure, first showing the raw data developed by the study.

A matrix tab for each study measure, showing data provided by each study – description, cost definitions, data collection and availability, analysis approach, labor, and notes. The matrix tab provides the scoring components for the top-level scoring matrix, including, for example, a qualitative rating on a scale of 1 to 5 for each study.

Low-scoring measures were considered more appropriate for primary research; a low numeric score indicated that little or no current, complete usable cost data were found. Navigant notes that the six gas measures were pre-selected by the Subcommittee and although those measures were scored, the quantitative scores were important only to the remaining 12 measures.

The study team also considered qualitative factors, such as the Subcommittee's initial priorities, geographic importance (e.g., air source heat pumps are more relevant to Mid-Atlantic States than New England), and customer sector.

**Table 3-2: Secondary Research Quantitative and Qualitative Factors Considered**

| Quantitative Factors | Qualitative Factors |
|---|---|
| Number of Sources | Subcommittee First Priority Measures |
| Data Vintage | Geographic Concerns - Mid-Atlantic, New England |
| Baseline Measure Cost Completeness | Residential vs. Commercial/Industrial |
| Efficient Measure Cost Completeness | Relative Cost-Effectiveness |
| Labor Breakouts Provided | Widgets vs. System Measures |
| Full Costs Provided | Available Budget (number of measures that could be researched) |

Table 3-3 shows the quantitative ratings for each measure. These ratings, along with the qualitative considerations, were presented to the Subcommittee in a report on December 20, 2010.

**Table 3-3: Secondary Research Quantitative Measure Ratings (lowest scoring measures deemed most in need of further cost research**

| Measure | Number of Sources Found | Data Vintage | Completeness: Baseline costs | Completeness: Efficient Options Covered | Completeness: Labor breakouts provided | Full Costs Provided if needed | Total Score |
|---|---|---|---|---|---|---|---|
| **EMV Subcommitte First Priority Measures** | | | | | | | |
| Residential Central Air Conditioners | 3 | 3 | 3 | 5 | 2 | 1 | **17** |
| Residential Air Source Heat Pumps | 3 | 3 | 3 | 5 | 2 | 1 | **17** |
| Residential Furnace Fans (e.g. ECM fans) | 3 | 1 | 3 | 5 | 2 | 0 | **14** |
| Commercial Unitary Air Conditioners | 3 | 1 | 3 | 5 | 0 | 1 | **13** |
| Residential Insulation Upgrades (attic, wall, basement | 3 | 3 | 3 | 5 | 5 | 1 | **20** |
| Residential Air Sealing | 3 | 3 | 0 | 2 | 5 | 1 | **14** |
| Residential Gas Furnaces | 3 | 0 | 3 | 1 | 2 | 1 | **10** |
| Residential Gas Boilers | 3 | 3 | 3 | 2 | 5 | 1 | **17** |
| Commercial Gas Boilers | 1 | 3 | 3 | 5 | 2 | 1 | **15** |
| Combination Heat Hot Water | | | | | | | **0** |
| Tankless On Demand | 3 | 3 | 0 | 2 | 2 | 1 | **11** |
| Indirect Water Heater | 1 | 3 | 0 | 2 | 0 | 1 | **7** |
| **EMV Subcommitte Second Priority Measures** | | | | | | | |
| Large commercial HVAC measures (e.g. chillers) | 1 | 3 | 3 | 5 | 2 | 1 | **15** |
| Variable Frequency Drives | 3 | 3 | 3 | 5 | 2 | 1 | **17** |
| Ductless Mini-Splits Air Conditioners and Heat Pump | 3 | 1 | 3 | 2 | 5 | 1 | **15** |
| Differential Dual Enthalpy Economizers | 1 | 1 | 0 | 2 | 2 | 0 | **6** |
| Commercial Lighting Controls | 3 | 3 | NA | 5 | 2 | 1 | **14** |
| Energy Management Systems | 1 | 3 | NA | 1 | 5 | 1 | **11** |

The study team's recommendations for primary research were limited by project resources to 12 measures. Without that limitation, the ICS team would have recommended that all measures on the initial Subcommittee list be subject to primary research. The team found considerable incompleteness and inconsistency in the existing cost data it reviewed. Some cost data were quite old or were updated estimates based on results from studies conducted a decade ago or longer. Studies sometimes reported material costs only or reported costs without making clear the extent to which labor and materials were included. Baselines in older materials did not always coincide with current baselines, and so on. For these reasons, the project team determined the time and effort required to vet and report the costs found in study data assessed during the secondary research would not be a good use of project resources.

### 3.2.1 Recommended List of Measures to Receive Primary Research

Navigant submitted its recommendations to the Subcommittee on December 21, 2010. The Subcommittee made its final decisions in a meeting attended by Navigant on January 14, 2011. The final list of primary research measures included the following, shown in Table 3-4. The Subcommittee accepted most of Navigant's recommendations, making the following changes:

- » ECM motors, which were a separate measure in the initial measure grouping, were combined with gas furnaces.
- » Residential insulation was not recommended as a highest priority but was designated by the Subcommittee for primary research.
- » Variable frequency drives (VFDs) were in the Subcommittee's second tier initially and did not rise to the top of the list; they scored relatively high, meaning quantitative data were better than other measures.

**Table 3-4: Measure Selected for Primary Research**

| Electric Measures* | Gas Measures |
|---|---|
| Insulation | Residential Gas Furnaces incl. ECMs |
| Air Sealing | Residential Gas Boilers |
| Residential Central Air Conditioning | Commercial Gas Boilers |
| Residential Air Source Heat Pumps | Residential Combination Heat and Hot Water Units |
| Commercial Unitary Air Conditioning | On-Demand Water Heaters |
| Commercial Lighting Controls | Indirect Water Heaters |

* Measures were deemed "Electric" only to distinguish them from the specific gas measures requested by the Gas Networks.

Measures not selected for primary research included ductless mini-split systems, and large commercial heating, ventilating, and air-conditioning (HVAC) systems (e.g., chillers, energy management systems, differential dual enthalpy economizers, VFDs, and Electronically Commutated Motors (ECMs) (with the latter included in gas furnaces). Navigant notes that given the data reviewed during secondary research, Navigant would have recommended that all measures receive additional primary research if project budget were not a limitation. The overall concerns about age, consistency, completeness, and other factors applied to the measures not selected similarly to those that were selected.

# 4. Phase 2: Primary Research Data Collection and Analysis

## 4.1 Introduction

In this section, Navigant describes the methodology used in developing the ICS analysis framework, its approach to data collection, and the analytical methods and assumptions Navigant used to produce costs for the project measures. The approach incorporates the acquisition of recent cost data, robust analysis, testing, and cross-referencing to other relevant sources, and feedback from primary sources and subject matter experts (the Technical Assistance Groups [TAGs] that provided independent input for each project measure). Throughout all phases, Navigant presented interim data summaries and preliminary analysis, vetting the outputs with key stakeholders within NEEP and its constituent program administrators that have unique perspectives of the Northeast residential and commercial market sectors. These quality control steps are essential to creating an accurate view of the marketplace and reasonable measure costs.

The cost assessment analysis methodology included the following:

- Data Collection
- Data Review and Assessment
- Measure Cost Calculation
- Incremental Cost Approach and Results
- TAG Review and Adjustment
- Conclusions

## 4.2 Data Collection

The process began with the team developing data collection instruments that were vetted with NEEP and technical advisors, and then tested to ensure that the device performance characteristics were clear (e.g., efficiency levels and sizes) and could be accurately costed in subsequent surveys, interviews, and research efforts. Testing also sought to ensure that installers would respond to the surveys, which interrupt their daily business. On testing we learned that several market-oriented questions, such as "What percentage of your sales are in efficient equipment as compared to standard efficiencies?", were distracting to installers and produce guesses rather than real answers. The team stripped out all non-essential questions and reduced the survey time to a maximum of ten minutes for most measures.[7] The revised, stripped-down surveys were then customized for each project measure. The project team ensured that a consistent approach was maintained to develop the incremental cost results for each measure. Each task and the analysis required were identified in order to streamline the process, maintain the desired level of quality, and to ensure the reporting of reasonable cost results.

[7] Surveys took longer where multiple technologies were involved, as in commercial lighting controls, or a variety of capacities and efficiencies were being researched for a measure.

In parallel with developing the data collection instruments, the research team also identified how products were being installed through the associated utility programs and how to develop the cost collection instruments that reflected these various delivery methods. The cost data collection approach relied on each measure's program delivery method. The program delivery method is defined as the process by which efficiency incentives and services reach customers. For example, a downstream program designed to provide rebates to customers who purchase high-efficiency equipment will rely on costs gathered from retail venues (e.g., appliance dealers), to calculate baseline inefficient equipment costs and efficient equipment costs incurred by participants. Similarly, measures offered through upstream or direct installation programs will generally rely on contractor and supplier interviews to acquire a comprehensive understanding of the pricing structure used in a particular service territory. Several different strategies and resources were used to collect relevant information on the measures addressed through this study. They included:

- Program Data:
  - Including data taken directly from the local energy efficiency program, and program-tracking databases from implementers.
- Primary Research:
  - Including interviews with contractors, equipment distributors and suppliers, retail managers, and on-site retail surveys.
- Secondary Research:
  - Including Internet research data, other secondary literature, and data supplied by industry-specific resources.

#### 4.2.1 Program Data

Program data detailing the installation characteristics for each participant were supplied to the project team to supplement the primary research efforts. This information was compiled in the tracking databases gathered by implementation contractors. This information supplemented the cost data with installation information, customer trends, market shares, and location. For example, implementers tracked the volumes of items installed by manufacturer. Volumes were tracked for various parameters and by contractor. Relevant sales data were also sometimes available. For these datasets, several trends including market shares and other key characteristics were calculated.

### *4.3 Primary Research*

Primary research is defined in this study as the cost of a measure as reported by the source providing the measure, such as a retailer, wholesaler, or installing contractor. This is in contrast with the definition of secondary research provided previously, which defines secondary sources as reports that provide cost information, but not specific costs from the sources providing the cost data. Primary research for the ICS was intended to produce the following results:

- Develop current full and incremental costs for 12 gas and 12 "electric" measures.[8]
- Provide both materials and labor costs.

[8] "Electric" is a term of convenience, intended only to distinguish the pre-selected group of gas measures from other measures selected for primary research.

» Determine the distinct markets among the NEEP member territories and provide costs for each of the markets identified.

» Provide cost curves that could be scaled by measure characteristics, as appropriate, and be adjusted over time to reflect changes in the markets.

» Develop transparent cost estimation workbooks that could be customized by program planners and other users to meet particular local needs.

Navigant based its primary research strategy on several key principles:

» The research would be closely focused on equipment actually receiving incentives in current energy efficiency programs within the study region.

» Program administrator databases and/or invoices would provide primary source materials, including makes and models and installer contact information.

» A standard interview protocol would be used, modified to accommodate individual measures.

» Interviews would be done by experienced Navigant staff who were knowledgeable about the study measures.

» Interviews would be conducted for installers throughout the NEEP member territories, subject to the availability of measure-level data.

» A TAG composed of EM&V Subcommittee members and other technical program administrator staff would provide input at every stage of the research, including preliminary and final cost results.

### 4.3.1 Concentration on Participating Equipment and Installers

The project team focused on participating equipment rather than conducting a broad market survey for several reasons. First, while there is a broad spectrum of equipment for many measures, a close examination of the equipment actually receiving incentives tends to show a limited number of manufacturers, makes, and models represented. For some equipment types, one or two manufacturers dominate the incentive market. One manufacturer accounted for approximately 70 percent of on-demand gas water heaters receiving incentives, for example. It is possible with some measures to obtain cheaper equipment but participating installers are not generally providing that equipment. This focus on equipment actually receiving incentives may have served to result in costs higher than expected if Navigant had looked at the entire market. However, if the entire market does not participate in a program, then costs for equipment offered for sale beyond the programs' sphere are not germane. Participating installers in many jurisdictions must agree to certain installation and performance standards to participate in the efficiency programs. Including equipment or installers that do not conform to prevailing efficiency program standards within the study frame would therefore not appropriately represent the segment of the efficiency market that program administrators operate within. Similarly, it is possible that some cost inflation comes about through limited offerings of energy-efficient equipment from manufacturers, distributors, and participating installers. In Navigant's experience with trade allies, it is not unusual to find that trade allies prefer to deal with brands and models they know well and believe will perform reliably. Thus, there may be some selection. Finally, we

know from projective studies such as the U.S. Department of Energy's work on appliance standards[9], that manufacturing costs differ greatly when comparing the current market baseline with efficient alternatives.

Concentrating on this segment of the market may produce results showing increased costs where energy-efficient equipment is bundled with premium features, such as more user-friendly controls, better warrantees, or features that do not increase the measure's energy efficiency performance. The project team encountered this circumstance in the ICS in the Residential Air Conditioning but did not find a way to net out non-energy feature costs.

### 4.3.2 Program Administrator Databases as the Primary Data Resource

Program administrator databases provided not only measure-specific data but also facilitated the installer interviewing process. Having very specific data allowed the project team to contact installers with highly specific information about equipment they sold and installed that received program administrator energy efficiency incentives. One of the barriers in reaching installers is that questions about a sensitive area like costs are attempts by their competitors to seek price information to the installer's disadvantage. Being able to say that X program administrator has provided specific information about the number of Model Y indirect water heaters, for example, is information that could only come from the program administrator and increases confidence that the call is legitimate. Having specific information also frames the interviewer to be a knowledgeable person, one worthy of taking the installer's time. Simply reaching installers is a major problem. In general, only about 30 percent of the installer contacts produced completed interviews. In addition to the legitimacy concern, seasonal concerns—heating systems in winter, cooling systems in early summer—constituted another barrier. In general, the project team found that program administrator databases did not hold information at a sufficient level of detail to facilitate the data collection strategy. Some program administrators did not offer some of the ICS measures, which reduced the population of data that could be collected. In most cases, the actual detailed databases were held and maintained by program implementation contractors who were working under contract to the program administrators. The data of interest for the ICS were not the data that implementation contractors normally reported to program administrators, which meant that getting the detailed data required someone to specifically extract the needed data, not a normal function for many. This extraction meant there were significant delays in acquiring data. That said, the project team found everyone involved to be most cooperative and helpful.

The implementation contractor databases were not uniform in structure or level of detail, a situation that varied by program for some program administrators. Those program administrators who offered programs over a number of years had many legacy databases; where new programs required different data, the new programs may have differing structures from the old.

[9] See http://www1.eere.energy.gov/buildings/appliance_standards/ for DOE's appliance standards program. Equipment-specific information is found in reports such as http://www1.eere.energy.gov/buildings/appliance_standards/residential/ac_central_1000_r.html

### 4.3.3 Standard Interview Protocols

To ensure consistency of approach for a number of study measures, Navigant developed a standard template protocol, and with TAG member input customized the standard template for each project measure to ensure that appropriate information about baseline and efficient measures was captured. Early protocol testing resulted in paring down the protocol to eliminate any questions not directly related to cost issues. Thus, an early set of questions asked about how much of an installer's business involved energy-efficient equipment vs. standard efficiency. Installers often did not have ready answers for these questions or guessed about the answers. Those questions slowed the interview to no great advantage for the study and in consequence, they were deleted. The interview protocols may be found in Appendix B.

### 4.3.4 Interviews Performed by Knowledgeable Navigant Staff

Successfully obtaining complicated information about baselines, sizes, efficiencies, and costs required knowledgeable interviewers. Obtaining costs for most study measures did not merely involve asking the cost of a particular widget. Rather, it required a conversation about several characteristics and their application in homes and businesses. High-efficiency furnaces, for example, require additional exhaust venting and the costs for that venting vary by the size and configuration of the basement or other part of the home where the furnace is installed. The interviewer sought the typical costs and therefore needed to be able to understand and discuss the variants and separate the typical from the unusual. Interviewers used an 80/20 approach; they asked for the costs and labor associated with the great majority (i.e., 80 percent of the installations not with the outliers where unique conditions require unique solutions). Navigant used experienced technical staff who were familiar with the study measures and could speak knowledgeably with installers.

### 4.3.5 Interviews to Be Conducted Throughout the NEEP Member Territories

The project team believed it was important to elicit responses from installers throughout the NEEP member territories, to ensure that regional variations in measures, labor costs, and other factors were captured. Although the team was able to discern six different markets using R.S. Means[10] data, obtaining material and labor cost data in as many of the markets as possible would serve as a check on the accuracy of the Means data. Navigant determined the total number of interviews that the study would support and allocated an equal number of interviews to each project measure. In addition, the project team allocated measure interviews approximately proportionally to each of the ICS markets. This allocation was modified to ensure the smallest markets had a minimum number of interviews, and was further modified by the availability of data, since not all program administrators were able to provide data to the project team for all measures.

### 4.3.6 Data Collection for Primary Research

Data collection for primary research for the 12 measures chosen by the Subcommittee consisted primarily of interviews conducted by experienced Navigant staff with equipment installers and distributors, using the interview protocols reviewed by NEEP and the Technical Advisory Group.

[10] R.S. Means provides comprehensive data to the building design and construction community on thousands of individual construction items and associated labor costs. The company developed cost factors for markets across the United States. Navigant used these cost factors to adjust Non-Regional Specific Costs developed for the ICS.

Navigant determined that 18 contractor and distributor interviews would be done per measure, considering the project resources available. In order to assure that interviews were conducted as broadly as possible, Navigant allocated interviews by market region. Table 4-1 shows the allocations.

**Table 4-1: Interview Allocations for Primary Research**

| State/Region | Distributor Interviews | Installer Interviews | Totals |
|---|---|---|---|
| **Gas Measures** | | | |
| Northern NE (ME/VT NH) | 4 | 8 | 12 |
| MA | 5 | 16 | 21 |
| CT/RI | 5 | 14 | 19 |
| New York State | 5 | 15 | 20 |
| New York Metro | 6 | 15 | 21 |
| Mid-Atlantic (MD, DE, DC) | 5 | 12 | 17 |
| **Quota Totals** | **30** | **80** | **110** |
| Completes | | | |
| | | | |
| **Electric Measures** | | | |
| Northern NE (ME/VT NH) | 4 | 8 | 12 |
| MA | 5 | 16 | 21 |
| CT | 5 | 14 | 19 |
| New York State | 5 | 15 | 20 |
| New York Metro | 6 | 15 | 21 |
| Mid-Atlantic (MD, DE, DC) | 5 | 12 | 17 |
| **Totals** | **30** | **80** | **110** |

Navigant completed 180 interviews. In order to achieve that, Navigant staff made 2,252 calls, shown in Table 4-2.

**Table 4-2: Distribution of Calls by Measure**

| | Residential Furnace | Residential Boilers | Commercial Boilers | On Demand Hot Water | Indirect Hot Water | Combination Heat and Hot Water | Insulation | Air Sealing | Residential AC | Air Source Heat Pumps | Commercial Lighting Controls | Unitary AC | Totals | Percentages |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interviews Completed | 15 | 20 | 15 | 21 | 15 | 15 | 15 | 18 | 19 | 13 | 5 | 10 | 181 | 8% |
| Interviews Declined | 4 | 4 | 8 | 11 | 17 | 25 | 15 | 4 | 23 | 11 | 15 | 43 | 180 | 8% |
| Unable to Reach | 53 | 50 | 53 | 69 | 69 | 69 | 83 | 73 | 129 | 55 | 0 | 90 | 793 | 35% |
| (Did not answer or return voicemail) | 16 | 74 | 76 | 101 | 101 | 109 | 113 | 95 | 171 | 79 | 20 | 143 | 1098 | 49% |
| Totals | 88 | 148 | 152 | 202 | 202 | 218 | 226 | 190 | 342 | 158 | 40 | 286 | 2252 | 100% |

Table 4-2 shows an overall success rate of only 8 percent for more than 2,000 calls made. This is a rather low response rate. Navigant would normally expect about a 15 percent rate overall with installers. The project team believes this reflects not only the normal difficulties in contacting installers, but also three other factors in play.

First, the team attempted to meet the allocation of calls throughout the region. However, for any given measure, the best data may have been available in one or two parts of the region. An easier choice would have been to simply call all the easy-to-reach contractors no matter what market they operated in; however, the project team attempted to take costs from around the region to the best extent possible.

Second, the quality of equipment and installer data varied greatly. In some cases there were very exact make and model measure descriptions, accompanied by good contractor contact information. In other data sets, measure descriptions were much more general, sometimes limited to descriptions such as "furnace" or "HVAC". Similarly, installer information varied greatly in detail with respect to installer location, contact information, and other factors. The more general the information, the more difficult it was to establish contact with the right individual, especially in larger installer organizations.

Third, the calls were affected by seasonal busy periods. The project team and the Subcommittee agreed that gas measures would be surveyed first. However, because Phase 2 could not go forward until Phase 1 research was completed and the Subcommittee designated the Phase 2 measures, the surveying began during the heating season. Similarly, cooling contractors by a matter of circumstance were not surveyed until the cooling season had begun, making contact that much more difficult. Any further work in seasonal measures should consider these factors.

While most measures achieved the interview quotas or were fairly close to them, some measures fell short. Commercial lighting was a particular problem; contractors would not respond. However, it became clear that the commercial lighting measures were commodities. Robust labor hours were obtained and costs were supplemented through Internet surveys. Where other measures fell short, it appeared the primary problem was seasonal difficulty reaching contractors, as noted above.

Several program administrators supplied data on the details of contractor installation activity. Navigant based its contractor interview goals on achieving a 90/10 confidence and precision or margin of error. Cost data collection for each measure was conducted in a manner to capture information over the entire NEEP region when possible. The retrieval of data over the entire region was also facilitated by each utility's network of participating contractors. Program administrators engage contractors, distributors, and regional suppliers in a manner to ensure that access to rebated equipment is available to all customers. Navigant followed a similar approach and made efforts to capture cost data from across the range of installing participants so that costs seen by all program administrator customers are accurately captured in the analysis.

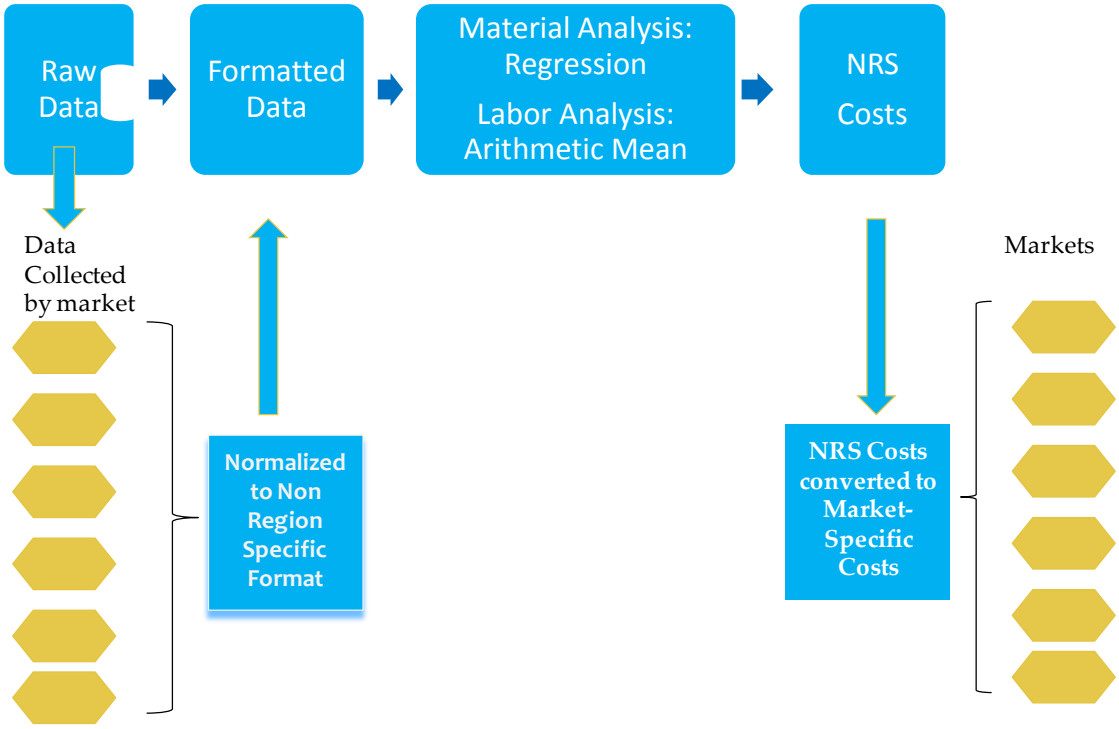
The team allocated equal numbers of interviews for each measure. Measure interviews were further allocated by region, proportionally to approximate region population/activity. (Some adjustments were made to ensure that the smallest states had reasonable numbers of interviews.) Interviewers attempted to observe the regional allocations but encountered two circumstances that worked against strict regional allocations. First, data quality of the measure information obtained from program administrator implementation contractors varied greatly. Some datasets had comprehensive measure information down to the make and model, and provided complete installer contact information. Some datasets listed measures as "HVAC" or "Lighting", and provided only general installer information, requiring further time to look up installer contact information and still more time to reach the right person, especially in larger installer companies. Second, once contacted, many contractors and suppliers chose not to participate in interviews at all or were only partially responsive to the team's inquiries. In general, about 70 percent of the contacts did not result in completed interviews.

The nature of the rebate structure and types of participants determined the methods used to capture cost data. Typically, telephone interviews were used for equipment contractors and suppliers. Telephone interview questions captured the cost of measures to the consumer. Costs for individual components were also captured as a verification method. Contractors were also asked about labor costs for a given measure. Total labor cost was recorded in addition to labor rates (dollars per hour), labor hours, quantity of technicians working, and any differences that may result from an efficiency change.

## *4.4 Data Review and Assessment*

In order to prepare collected data for analysis, Navigant normalized the cost data to provide a single analysis platform for each measure. Using the market factors described in Section 1, all cost data were normalized into Non-Region Specific (NRS) formats. For example, cost data on gas furnaces collected from Vermont in Northern New England were divided by the Northern New England, Market 1, cost factor 0.85; data on gas furnaces collected from Massachusetts in Central/Southern New England, Market 2, were divided by 1.05, normalizing the VT and MA data to the Non-Regional Specific platform. The data were then analyzed as a single data set, producing the NRS value for the measure. The NRS value was then multiplied by the appropriate factor for each market and reported in the report tables. Figure 4-1 describes the process graphically.

**Figure 4-1: Cost Analysis Process Including Formatting, Non-Regional Specific (NRS) Cost Development, and Final Cost Determination for Each Market**




Following the data collection process, all costs were examined and reviewed to ensure consistency and quality. On a given measure, costs could be gathered from multiple sources and may have included different combinations of equipment cost, labor costs or hours, wholesale markups, installer markups, and so on. The cost assessment results are intended to report only the cost difference resulting from an increase in efficiency. Consequently, each differing data source was scrutinized to be clear which cost elements were included or excluded. Further, comparisons and triangulations were performed to ensure that data were consistent. The data review and assessment process normalized costs to a common base, identified and isolated differences in markups between delivery streams, and screened costs for outliers and errors.

The data review and assessment process included the following:

- Quality Control
- Cost Adjustments
- Identification of Cost Variations
- Estimation of Precision

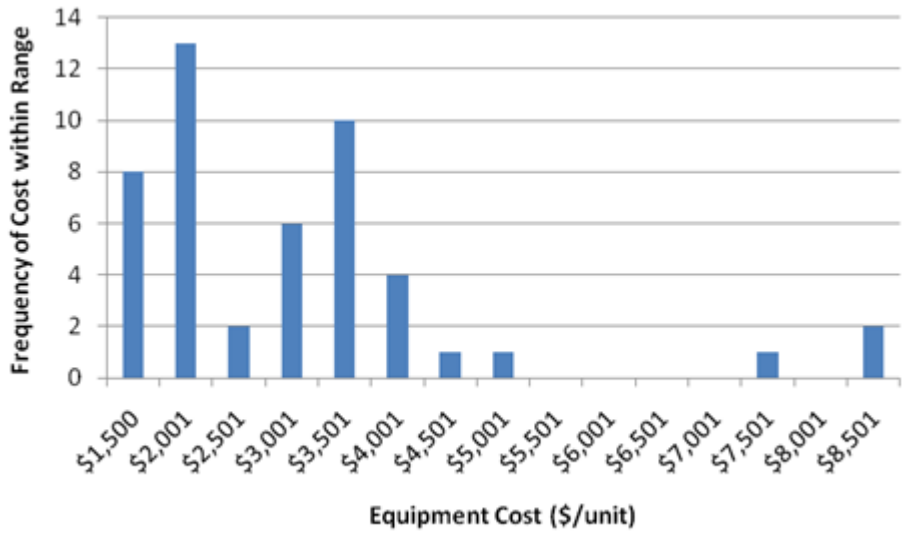
### 4.4.1 Quality Control

Data review and assessment for each measure starts with quality control. Secondary sources, Internet costs, and similar measures in other programs were referenced to verify that the cost information was accurate. Costs gathered through telephone interviews from contractors and distributors were verified for consistency. For example, contractors typically quote costs as total installed costs. Navigant asked about materials and labor and asked typical labor rates and installation hours. Quotes for total labor costs were checked against the quoted labor rates and man-hours and contractors were asked for clarification when discrepancies appeared.

One key function of the quality control step was the screening of outliers. After the Cost Team compiled a full raw dataset, the entire set was examined for points that are either too high or too low when compared to the entire sample. While equipment costs, labor rates, and labor hours did vary from source to source, these data points typically fell within a discernable range. Navigant typically used 40 percent as the outlier bound. That bound might be adjusted if measures were highly diverse in character, or if there was a tight grouping of the central tendencies in the measure costs reported.

Larger datasets improved the visibility of this range. For example, for combination heat and hot water systems, Navigant gathered 49 equipment cost data points. Three costs were considered outliers while the remaining 46 were used to develop the final incremental costs. These outliers have costs that were more than twice that of the average of the non-outliers (approximately $3,000 per unit). Navigant controlled for size, efficiency or other important measure characteristics in making these determinations. Figure 4-2 illustrates these outliers in relation to the remaining sample.

**Figure 4-2: Histogram of Cost Points: Combination Heat and Hot Water Systems**




### 4.4.2 Cost Adjustments

Primary cost data was collected from contractors across several states. Due to the inherent differences in costs from one area to another (e.g., the cost of labor and materials is typically greater in NY than in VT),

Navigant adjusted all material and labor cost points to represent NRS data using R.S. Means City Cost Indexes (CCI). R.S. Means (http://rsmeans.reedconstructiondata.com/) is a private cost information source for the construction and equipment industries produced by Reed Construction Data that compiles up-to-date estimates for equipment and labor costs. Costs are also specified by city and region through the CCI tool. R.S. Means data is an industry standard and is frequently referenced by facility owners, developers, architects, engineers, and contractors in order to develop accurate cost estimates for construction projects and large equipment procurements.

Table 4-3 provides a regional breakdown of markets involved in the ICS. The adjustment process allowed Navigant to collect data throughout the ICS region and using the City Cost Indices, to apply those costs to each study region. For example, if the cost provided from a contractor in New York Metro for a piece of equipment was $2,000, then the NRS cost would be:

NRS = Original State Cost ($)/Average Adjustment Factor for Original State or Area

NRS = $2,000/1.26

NRS = $1,593

The same method was used to adjust all labor costs.

**Table 4-3: Measure Summary**

| Market | Market Code | Regions | Average Adjustment Factor |
|---|---|---|---|
| Northern New England | 1 | ME, VT, NH | 0.85 |
| Central/Southern New England | 2 | MA (exc. Boston), RI, most CT | 1.05 |
| New England City | 3 | Boston, Providence | 1.12 |
| NY Metro | 4 | NYC, Metro, Suburbs, Southeast CT, | 1.26 |
| NY Upstate | 5 | Buffalo, Rochester, etc. | 0.99 |
| Mid-Atlantic | 6 | MD, DE, DC | 0.92 |
| Non-Regional Specific Average | - | - | 1.00 |

Some Internet costs were included in the analysis to augment and quality control (QC) the contractor data. Internet costs did not include a contractor markup; therefore, a match-pairs analysis typically determined the percentage cost difference between similar equipment sold by contractors and Internet retailers. A matched-pairs analysis involves pairing data points from one group (e.g., contractor cost points) with another group (e.g., Internet cost points) on a basis of matching factors (e.g., manufacturer, efficiency, input capacity). This method minimizes the effects of extraneous variables. For example, the same unit cost would be estimated through two sources, a contractor and the Internet, and then those costs would be compared to determine the cost difference. This cost difference was applied to the Internet cost as a contractor markup. A matched-pairs analysis involves pairing data points from one group (e.g., contractor cost points) with another group (e.g., Internet cost points) on a basis of matching

factors (e.g., manufacturer, efficiency, input capacity). This method minimizes the effects of extraneous variables. For example, the same unit cost would be estimated through two sources, a contractor and the Internet, and then those costs would be compared to determine the cost difference. There has been some review discussion about the extent to which markups are included in Internet prices. Navigant's review of comparable equipment comparing data obtained from contractors with a sample of Internet costs indicates that there is comparability on equipment cost only when a standard markup is applied to the Internet prices.

Secondary sources used for verifying costs often originate from older work conducted in different regions. The project team adjusted older cost data by accounting for inflation. The U.S. Bureau of Labor Statistics (BLS) publishes Producer Price Indices (PPIs) that measure the average change over time in the selling price of specified goods.[11] For example, PPIs are published for lighting products and HVAC products. The ratio of PPIs for given years is used to inflate reference costs to 2010 dollars. PPIs were used when cross-checking the NEEP residential boiler costs against the DOE residential boiler costs. DOE costs were originally calculated in 2006$. Therefore, Navigant inflated those numbers with the PPI for "steel heating boilers (15 psi or less) and all hot water heating boilers (except parts)." The boilers' PPI inflated 2006$ by 118 percent to obtain 2010$.

### 4.4.3 Identification of Cost Variations

Variations in total cost and incremental costs for equipment within a measure description were analyzed to determine the root cause. Variations existed among retailers, manufacturers, brands, and regions. Differences were quantified and trends identified. Certain brands in the residential market are considered premium product lines and include additional markups. Navigant identified and isolated those markups so that incremental costs do not inadvertently include the difference between standard and premium efficient equipment. However, some products, such as residential air conditioning, are offered only as premium products. In those instances, we did not isolate markups that result from the addition of features in many energy-efficient products that may increase the product's value to the customer, such as better controls, longer warranties, and other features that do not enhance the energy efficiency of those products. The report addresses this issue elsewhere.

## *4.5 Measure Cost Calculations*

The project team used several methods to calculate costs in a consistent overall framework. Measure calculations included simple average, weighted average, regression models, and custom cost estimates. For each ICS measure, one method, or a combination of methods, was used to arrive at the baseline and efficient measure costs for the equipment analyzed. The methods selected for each measure depended on the cost source, the nature of the measure, and the amount of available data. Navigant ensured that the most rigorous level of analysis possible was utilized for each measure. The methods used to develop incremental measure costs included:

[11]. *Producer Price Indexes*. U.S. Bureau of Labor Statistics, U.S. Department of Labor. http://www.bls.gov/ppi/

- Simple Average
- Weighted Average
- Regression Modeling
- Custom Cost Estimates

### 4.5.1 Simple Average

The simple average method takes all cost observations for a particular measure and averages them, discarding outliers in some cases where a particular observation appears considerably different than the other values.

### 4.5.2 Weighted Average

The weighted average is similar to the simple average but assigns more weight (i.e., value) to certain data points. These weights capture the relative importance of certain parameters within the data set and their impact on the final calculated mean. Weights are typically based on market shares. Examples would include contractor, distributor, or retailer sales volumes or the distribution of a particular feature (e.g., ton size for HVAC equipment) within the market.

### 4.5.3 Regression Modeling

Regression modeling is a form of analysis that attempts to quantify the behavior of uncertain parameters relative to other observable, and potentially influential, variables. Relevant performance factors were incorporated as independent variables in the cost models for measures analyzed using this approach.

### 4.5.4 Custom Cost Estimates

This approach was typical of "engineered" and/or technically complex types of measures. Custom cost estimates were employed where a unique equipment or system configuration needed to be defined by the project team and a cost estimate "built up" for the specific technical details of the measure.

## *4.6 Incremental Cost Approach and Results*

After the cost data has been reviewed for quality and processed for use in calculations, the final incremental cost results were developed. The incremental cost and the calculation method used for each measure are dependent on the program structure and rebate delivery method.
Incremental costs for each measure were developed among the following measure scenarios:

- Replace-on-Burnout
- Retrofit
- New Construction

### 4.6.1 Replace-on-Burnout/End of Useful Life

*Replace-on-burnout incremental cost ($) = Measure installed cost ($) – Baseline installed cost ($)*
*Installed cost ($) = Material ($) + Labor ($)*

Several measures, including the majority of measures in residential programs, assume that consumers will install new equipment after their existing equipment has failed. This replace-on-burnout application assumes that consumers are required to install new equipment regardless of the programs' existence. The baseline is defined as the minimum efficiency equipment that a consumer installs in the absence of an energy efficiency program incentive. The baseline is often defined by the program and based on federal efficiency standards or local building code requirements.

In the replace-on-burnout scenario, the incremental cost is the difference between the efficient and baseline costs. The full cost for the baseline was considered because it was assumed that the consumer would be burdened with that cost even in the absence of the program. Therefore, only the cost to achieve higher efficiency above the baseline was included. Labor costs were not included in the replace-on-burnout incremental cost when the amount of labor required did not vary across the range of efficiencies (i.e., the incremental labor cost was $0). Incremental labor costs were included, however, if an efficient level required additional labor to install a technology specific to a level.

### 4.6.2 Retrofit

*Retrofit incremental cost ($) = Measure material cost ($) + Measure labor cost ($)*

Commercial lighting measures are typically installed in a retrofit action. That is, these measures are implemented where existing equipment is currently in place and while that equipment still has remaining useful life. In the absence of the program, it is assumed that the efficient equipment would not be installed and the existing equipment would remain in place. As a result, the effective baseline cost is $0.

The incremental cost is the full cost of the measure equipment and the full labor cost for installation. Unlike the replace-on-burnout application, the existing equipment has remaining useful life. Therefore, the consumer would not be burdened with the cost for a baseline replacement of any efficiency level in the absence of the program.

### 4.6.3 New Construction

*New construction incremental cost ($) = Measure material cost ($) – Baseline material cost ($)($)+applicable labor cost if any*

Measures intended for commercial new construction are typically incorporated into the design at a stage of the building project before any construction work begins. These measures are included in the design in place of standard equipment that is the lowest efficiency level possible and considered the baseline. Federal standards and/or local building codes dictate what the minimum requirements are for a given installation and these serve as the baseline.

Similar to the replace-on-burnout application, in new construction it is assumed that the builder would be burdened with the cost of installing the baseline equipment even in the absence of the program. Therefore, that baseline cost is considered in the cost assessment and only the cost to achieve higher efficiency above the baseline is included in the incremental cost. Labor costs are also handled similarly as with replace-on-burnout situations. New construction incremental cost is considered $0 if labor does not

vary across the range of efficiencies. However, incremental labor cost is considered if an efficiency level required additional labor to install a technology specific to a level.

## *4.7 Estimation of Uncertainty*

Navigant examined the variance in the measure data by conducting a precision analysis at the 90 percent Confidence Interval (CI). Although most cost variations were in the range of 10 percent, Navigant found some wider variances in measures in baseline costs and in some labor estimations efficient measure costs. The project team determined there were several causes of uncertainty. Some of the larger variations in efficient measure costs were due to outlier costs that were subsequently removed from the analysis dataset; Residential Air Conditioning was the most noticeable of these. Some variations were due to different installer conceptions of what the baseline costs would be, especially where a different technology was involved, as in baseline combination heat and hot water, baseline labor regarding on demand water heaters. Commercial lighting controls and insulation both consist of a variety of sub measures. Commercial lighting controls sub measures ranged in cost by a factor of three among the different types of controls studied and some sub measures had wider cost variations than others. The insulation measure included multiple materials and scenarios; some, such as basement wall insulation, are relatively but are labor intensive, showing variations in labor costs. These factors, particularly analyzing complex measures, resulted in some higher than expected variances. Table 4-4 shows the variances at the 90 percent CI for baseline and efficient measure materials and labor, as well some sub measures.

Navigant determined variances for materials and for labor for baseline and efficient measures. This approach, required in the ICS design, permitted this component-level examination. However, because the components were not all homogeneous or always equal in quantity, it was not possible to determine a measure of precision around the total installed measure costs. In order to do that, the study would have been designed at the outset to collect full measure costs and employ an analysis that did not separately consider the materials and labor components as was done in the ICS.

**Table 4-4. Analysis of Materials and Labor Variances at the 90 Percent Confidence Interval**

| | | | Material | | Labor | Labor Hours | |
|---|---|---|---|---|---|---|---|
| Sector | Measure | Sub-Measure | Baseline | Measure | Rate | Baseline | Measure |
| Residential | Insulation | All Insulation | N/A | 19.3% | 5.00% | N/A | 28.7% |
| | | Attic Cellulose | N/A | 12.5% | | | |
| | | Attic Fiberglass | N/A | 27.1% | | | |
| | | Attic Foam | N/A | 13.2% | | | |
| | | Wall Cellulose | N/A | 11.1% | | | |
| | | Wal Fiberglass | N/A | 14.5% | | | |
| | | Wall Foam | N/A | 16.5% | | | |
| | | Basement Wall | N/A | 34.2% | | | |
| | | Basement Rim Joists | N/A | 24.8% | | | |
| Residential | Indirect Hot Water | | 10.21% | 8.34% | 2.14% | 21.9% | 25.5% |
| Residential | Furnace | | 10.89% | 5.00% | 2.14% | 25.7% | 16.7% |
| Residential | Combination Heat and Hot Water | | 17.34% | 6.46% | 2.14% | 32.9% | 13.1% |
| Residential | Central Air Conditioning | | 11.88% | 6.39% | 2.14% | 13.5% | 13.5% |
| Residential | Air Sealing | | N/A | 13.1% | 13.94% | N/A | 18.0% |
| Residential | Boilers | | 17.34% | 12.14% | 2.14% | 32.90% | 14.26% |
| Residential | Air Source Heat Pumps | | 8.91% | 4.60% | 2.14% | 8.84% | 8.84% |
| Residential | Tankless Water Heaters | | 10.21% | 8.89% | 2.12% | 21.89% | 16.78% |
| Commercial | Boilers | | 15.82% | 3.48% | 16.77% | 12.92% | 12.83% |
| Commercial | Lighting Controls | All Controls | N/A | 14.61% | 5.23% | N/A | 26.6% |
| | | Fixed Photocontrol | N/A | 12.92% | | | |
| | | Turn-Lock Photocontrol | N/A | 16.25% | | | |
| | | Wired-in Photocontrol | N/A | 8.52% | | | |
| | | Screw-in Photocontrol | N/A | 11.55% | | | |
| | | Swivel Photocontrol | N/A | 19.36% | | | |
| | | Button Photocontrol | N/A | 23.81% | | | |
| | | Shorting Cap Photocontrol | N/A | 9.85% | | | |

## *4.8 Technical Advisor Group Review and Adjustment*

Once Navigant completed its analysis of each project measure, Navigant sent the completed project workbook, containing all calculations and explanations, to the EMV Forum ICS project manager, who forwarded the workbooks to at least two TAG members for review. TAG members were charged with conducting a reality check on the results and made comments to the team, either supporting the findings or raising questions. TAG questions were not confined to the results only. At various times, Navigant and TAG members discussed analysis explanations, methodology, sources, and baseline and efficient equipment costs, on any given measure. In one instance, a TAG member raised a recent study on residential air conditioning published by the DOE. The DOE study had significantly lower incremental costs compared to the ICS results. On further inquiry, it became clear that the DOE study was not a current market study but a projection of what might happen in the market if the residential air conditioning baseline was raised from the current SEER 13 to SEER 15. That standard change would affect the scale of manufacturing SEER 15 units dramatically, having an impact on manufacturing costs but also moving the scale of premium products to higher efficiency levels. The discussion around this measure did not change the ICS incremental costs but did lead to further discussion of costing non-efficiency premium features.

## *4.9 Conclusions*

The cost methodologies presented in this section were incorporated into each of the NEEP spreadsheet tools compiled for this analysis effort. These spreadsheets were set up to allow data review in order to identify the data collection and documentation process, the sources used, and the analysis approaches taken. Additionally, the data spreadsheets allowed for customization so that users (e.g., energy efficiency program planners) can generate custom results and custom analyses can be accommodated.

The transparent and standardized incremental cost approach also benefitted the feedback process with NEEP and its constituents. Accessible spreadsheets facilitated responses to inquiries and adjustments resulting from comments in a timely and efficient manner. This communication process would not have been possible with static cost numbers or one in which the analysis assumptions and calculations were not made available to the reviewers and ultimate end users.

# 5. Measures Cost Results

In this section, Navigant presents the individual measure characterization tables and then describes key issues concerning data collection and analysis for primary research on each of the project measures. These descriptors include:

- Definition of measure baselines and efficient measures (e.g., sizes, capacities, and specifications)
- Data sources employed, type and geographic
- Issues in data collection (e.g., difficulties in reaching contractors, contractor responsiveness, and definitions of measures)
- Data analysis – approaches used (e.g., regression, weighted averages), plus any concerns in analyzing the data
- Informal reviews by TAG members, results of comments (changes in costs, presentation)
- Any unresolved issues

The cost tables found in this section are NRS costs. Readers can determine the costs in each individual market by multiplying the NRS costs by the appropriate market adjustment factor, shown in Table 5-1 below. For users' convenience, Navigant has provided an Appendix A that shows by market the costs for each project measure. Full cost information, including inputs, calculations, and final results are also provided in electronic workbooks, which are available through the EM&V Forum.

**Table 5-1: Markets and Adjustment Factors**

| Market | Market Code | Market Territory | Adjustment Factor[12] |
|---|---|---|---|
| Northern New England | 1 | ME, VT, NH | 85.1 |
| Central/Southern New England | 2 | MA , RI, most CT | 105.3 |
| New England City | 3 | Boston, Providence | 111.5 |
| Metro New York | 4 | NYC, metro suburbs Southwest CT | 125.6 |
| Upstate New York | 5 | Albany, Buffalo, Rochester, balance of the state | 98.9 |
| Mid-Atlantic | 6 | MD, DE, DC | 91.5 |
| Non-Regional Specific NRS) | - | - | 100 |

[12] Adjustment Factor is a cost factor applied to the identified markets to normalize costs collected in each market, and to then determine the costs in each market following analysis of the each measure data set. A full explanation is provided in Section 4 of the report.

**Table 5-2: Characterization of Gas Measures**

| | Residential Gas Furnaces | Residential Gas Boilers | Commercial Gas Boilers | Tankless Water Heaters | Indirect Water Heaters | Combination Heat/Hot Water Heater |
|---|---|---|---|---|---|---|
| Application | ROB | ROB | ROB | ROB/NC | ROB/NC | ROB/NC |
| Size Range | < 120 kBTU/H | < 300 MBH | 300 - 2,500 MBH | 188, 199 MBH | 30 – 65 Gallons | < 200 MBH |
| Efficiency Metric | AFUE | AFUE | Thermal Efficiency | Energy Factor (EF) | N/A | Baseline: AFUE<br>Measure: CAE |
| Baseline | 80% | 80% | 80% | 40 gal. Storage WH w/ 59 EF | 40 gal. Storage WH w/ 59 EF | 80 AFUE hot water gas boiler |
| Efficiency Level(s) | » 90%<br>» 92%<br>» 94% | » 85%<br>» 90% | » 85%<br>» 90% | • 82 EF<br>• 94 EF<br>• 95 EF<br>• 96 EF | Indirect WH Installed | • 90 CAE<br>• 91 CAE<br>• 92 CAE<br>• 93 CAE<br>• 95 CAE |
| Cost Basis | $/Unit | $/Unit | $/Unit | $/Unit | $/Unit | $/Unit |
| Material Analysis | Regression | Regression | Regression | Regression | Regression | Regression |
| Labor Analysis | Weighted Average | Weighted Average | Weighted Average | Weighted Average | Weighted Average | Weighted Average |

Notes:
CAE = Combined Appliance Efficiency; AFUE = Annual Fuel Utilization Efficiency
ACH = Air Changes per Hour
EF = Energy Factor

**Table 5-3: Characterization of "Electric" Measures**

| | Residential Insulation | Residential Air Sealing | Residential Central AC | Residential Air Source Heat Pumps | Commercial Lighting Controls | Commercial Unitary AC |
|---|---|---|---|---|---|---|
| Application | RET/NC | RET/NC | ROB/NC | ROB/NC | RET/NC | ROB/NC |
| Size Range / Products Covered | » Attic<br>» Wall<br>» Basement Wall<br>» Basement Rim Joist | Residential buildings < 3000 ft² | < 65,000 Btu/h | < 65,000 Btu/h | • Photo-controls<br>• Timers<br>• Occupancy Sensors | 5.4-11.3 tons<br>11.3-20 tons<br>20-63.3 tons < 200 MBH |
| Efficiency Metric | R-Value | ACH | SEER | SEER/HSPF | N/A | EER |
| Baseline | No Insulation | 0.50 | 13 | 13 / 7.7 | No Lighting Controls | Varies by size |
| Efficiency Level(s) | » Attic: R-19, 38, 60<br>» Wall: R-13, 19, 21<br>» Basement Wall: R-16<br>» Basement RJ: R-17 | 0.35 | • 14.5<br>• 15<br>• 16+ | • 14.5 / 8.2<br>• 15 / 8.5 | Controls installed | Two Tiers<br>Varies by size |
| Cost Basis | $/ft² | $/House or $/CFM Reduced | $/Unit | $/Unit | $/Unit | $/ton |
| Material Analysis | Regression | Arithmetic Mean | Regression | Regression | Regression | Regression |
| Labor Analysis | Weighted Average | Arithmetic Mean | Weighted Average | Weighted Average | Arithmetic Mean | Weighted Average |

Notes:
ACH = Air Changes per Hour
EF = Energy Factor
HSPF = Heating Seasonal Performance Factor

### Table 5-4: Incremental Cost Results

| Measure | Results | | | |
|---|---|---|---|---|
| **Residential Gas Furnaces ($/Unit)** | Size (kBTU/H) | 90 AFUE | 92 AFUE | 94 AFUE |
| | 60 | $1,131 | $1,284 | $1,438 |
| | 70 | $1,140 | $1,294 | $1,448 |
| | 80 | $1,150 | $1,304 | $1,458 |
| | 90 | $1,160 | $1,314 | $1,468 |
| | 100 | $1,170 | $1,324 | $1,478 |
| | 120 | $1,190 | $1,343 | $1,497 |
| **Residential Gas Boilers ($/Unit)** | Size (MBH) | 85 AFUE | 90 AFUE | |
| | 50 | $501 | $2,142 | |
| | 75 | $630 | $2,271 | |
| | 105 | $784 | $2,425 | |
| | 150 | $1,015 | $2,656 | |
| | 200 | $1,272 | $2,913 | |
| | 300 | $1,785 | $3,427 | |
| **Commercial Gas Boilers ($/Unit)** | Size (MBH) | 85 AFUE | 90 AFUE | |
| | 300 | $625 | $3305 | |
| | 500 | $1385 | $4064 | |
| | 750 | $2334 | $5013 | |
| | 1000 | $3283 | $5962 | |
| | 1500 | $5181 | $7860 | |
| | 2000 | $7079 | $9758 | |
| **Tankless Water Heaters ($/Unit)** | Size (MBH) | SWH Size (Gal) | 82EF | 94EF |
| | 180 | 30-48 | $2,631 | $3,193 |
| | 199 | 50-65 | $2,721 | $3,283 |
| **Indirect Water Heaters ($/Unit)** | Size (MBH) | Cost | | |
| | 40 | $1,086 | | |
| | 60 | $1,448 | | |
| | 80 | $1,769 | | |
| | 120 | $2,334 | | |
| **Combination Heat/Hot Water Heater ($/Unit)** | Size (MBH) | 90 CAE | 93 CAE | 95 CAE |
| | 110 | $1,062 | $2,093 | $2,780 |
| | 120 | $982 | $2,013 | $2,700 |
| | 126 | $934 | $1,965 | $2,652 |
| | 150 | $742 | $1,773 | $2,460 |
| | 199 | $350 | $1,381 | $2,068 |

| Measure | Results |
|---|---|

**Residential Insulation ($/ft²)**

- Attic Insulation:

| | R-19 | R-38 | R-60 |
|---|---|---|---|
| Cellulose | $2.07 | $2.44 | $2.87 |
| Fiberglass | $1.54 | $1.98 | $2.50 |
| Foam | $2.46 | $3.65 | $5.04 |
| Average | $2.02 | $2.69 | $3.47 |

- Wall Insulation

| | R-13 | R-19 | R-21 |
|---|---|---|---|
| Cellulose | $1.90 | $2.20 | $2.30 |
| Fiberglass | $1.54 | $1.65 | $1.69 |
| Foam | $1.24 | $2.21 | $2.54 |
| Average | $1.56 | $2.02 | $2.17 |

- Basement Insulation

| | |
|---|---|
| Basement Wall (R-16) | $2.93 |
| Basement Rim Joist (R-17) | $5.97 |

**Residential Air Sealing ($/House, $/CFM Reduced)**

| House Size (ft²) | Cost ($) | CFM Reduced | Cost ($) |
|---|---|---|---|
| 1,200 | $555 | 250 | $311 |
| 1,500 | $694 | 500 | $621 |
| 2,000 | $926 | 750 | $932 |
| 2,500 | $1,157 | 1000 | $1,243 |
| 3,000 | $1,388 | | |

**Residential Central AC ($/Unit)**

| Size (tons) | 14.5 SEER | 15 SEER | 16+ SEER |
|---|---|---|---|
| 2 | $1,141 | $1,382 | $2,585 |
| 3 | $1,171 | $1,412 | $2,615 |
| 4 | $1,200 | $1,441 | $2,644 |
| 5 | $1,230 | $1,470 | $2,674 |

**Residential Air Source Heat Pumps ($/Unit)**

| Size (tons) | 14.5 SEER | 15 SEER |
|---|---|---|
| 2 | $993 | $1,128 |
| 3 | $1,335 | $1,470 |
| 4 | $1,677 | $1,812 |
| 5 | $2,019 | $2,154 |

| Measure | | Results | | |
|---|---|---|---|---|
| **Commercial Lighting Controls ($/Unit)** | Fixed Photo control | $93 | | |
| | Turn-Lock Photo control | $175 | | |
| | Wired-in Photo control | $80 | | |
| | Screw-in Photo control | $88 | | |
| | Swivel Photo control | $92 | | |
| | Button Photo control | $89 | | |
| | Shorting Cap Photo control | $103 | | |
| | Electronic Timer | $134 | | |
| | Digital Timer | $66 | | |
| | Switch Timer | $181 | | |
| | Passive Infrared Occupancy Sensor (Ceiling) | | | $274 |
| | Passive Infrared Occupancy Sensor (Wall) | | | $125 |
| | Passive Infrared & Ultrasonic Occupancy Sensor (Ceiling) | | | $281 |
| | Passive Infrared & Ultrasonic Occupancy Sensor (Wall) | | | $199 |
| **Commercial Unitary AC ($/Unit)** | Size (Btu/h) | Tier 1 | Tier 2 | |
| | 65,000 | $123 | $174 | |
| | 135,000 | $184 | $235 | |
| | 240,000 | $102 | $138 | |

## *5.1 Gas Measure Individual Discussion*

### 5.1.1 Residential Gas Furnaces

**Measure Specifications**

The residential furnace analysis covers gas-fired, forced-air furnaces with input ratings between 60 and 120 MBH. The baseline and high-efficiency cases were defined in terms of AFUE, based on review of federal specifications and several TRMs published by NEEP sponsors and other jurisdictions, as shown in Table 5-5.

**Table 5-5: Efficiency Level Specifications for Residential Furnaces**

| Efficiency Level | AFUE |
|---|---|
| Baseline (Federal Minimum Standard) | 80% |
| High Efficiency - Tier 1 (ENERGY STAR) | ≥ 90% |
| High Efficiency - Tier 2 | ≥ 92% |
| High Efficiency - Tier 3 | ≥ 94% |

**Data Sources**

Navigant received contact information provided by Gas Networks, National Grid, New York State Energy Research and Development Authority (NYSERDA), and Vermont Gas to conduct interviews with contractors. Table 5-6 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-6: NEEP-Supplied Information for Residential Furnaces**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| Gas Networks | 1,600 contractor names and model numbers installed | MA |
| National Grid | 166 contractor names, phone numbers, and model numbers installed | MA, RI, NH, and NY |
| NYSERDA | 176 contractor names, phone numbers, and model numbers installed | NY |
| Vermont Gas | 15 contractor names and phone numbers | VT |

**Data Collection**

The Navigant team completed 15 interviews, with 88 calls having been placed. Table 5-7 summarizes the call outcomes for residential gas furnaces. The calls that did not result in successful interviews were primarily because Navigant was unable to reach the proper person. The companies that declined the interview told Navigant that they were either too busy, they did not have the information needed for the interview, or they were unwilling to share their cost data. It is possible that respondent incentives would have increased the response rates. Navigant has not offered such incentives in other similar research but would consider it for future work.

**Table 5-7: Call Outcomes for Residential Furnaces**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 15 | 17% |
| Interviews Declined | 4 | 5% |
| Unable to Reach (Did not answer or return voicemail) | 53 | 78% |
| Total | 88 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 32 data points collected from interviews with contractors and 23 additional cost points from online vendors. Navigant conducted interviews in MA, VT, and upstate NY.

**Results**

The incremental cost results for residential furnaces are presented in Table 5-8. The Tier 1 incremental costs represent the cost associated with the increase from 80 percent to 90 percent in AFUE, the Tier 2 incremental costs represent the cost associated with the increase from 80 percent to 92 percent in AFUE, and the Tier 3 incremental costs represent the cost associated with an increase from 80 percent to 94 percent. All costs are presented on a per-furnace basis.

**Table 5-8: Residential Furnace Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (kBtu/h) | 90 AFUE | | 92 AFUE | | 94 AFUE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 60 | $828 | $1,131 | $982 | $1,284 | $1,136 | $1,438 |
| 70 | $838 | $1,140 | $992 | $1,294 | $1,146 | $1,448 |
| 80 | $848 | $1,150 | $1,002 | $1,304 | $1,156 | $1,458 |
| 90 | $858 | $1,160 | $1,012 | $1,314 | $1,165 | $1,468 |
| 100 | $868 | $1,170 | $1,021 | $1,324 | $1,175 | $1,478 |
| 120 | $887 | $1,190 | $1,041 | $1,343 | $1,195 | $1,497 |

Notes:
Baseline = 80% AFUE furnace
Total Installed Cost = Material Cost + $306 Labor

**Issues for Further Research**

No major issues arose during the residential furnace analysis requiring further research.

### 5.1.2 Residential Gas Boilers

**Measure Specifications**

The residential boiler analysis covers gas-fired hot water boilers with input ratings less than 300 kBtu/h. The baseline and two high-efficiency cases were defined in terms of AFUE, based on review of federal specifications and several TRMs published by NEEP sponsors and other jurisdictions, as shown in Table 5-9 .

**Table 5-9: Efficiency Level Specifications for Residential Boilers**

| Efficiency Level | AFUE |
|---|---|
| Baseline (Federal Minimum Standard) | 80% |
| High Efficiency - Tier 1 (ENERGY STAR) | ≥ 85% |
| High Efficiency - Tier 2 | ≥ 90% |

**Data Sources**

Navigant received contact information provided by Gas Networks, National Grid, and Vermont Gas to conduct interviews with contractors. Table 5-10 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-10: NEEP-Supplied Information for Residential Boilers**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| Gas Networks | 125 contractor names and model numbers installed | MA |
| National Grid | 115 contractor names, phone numbers, and model numbers installed | MA, RI, NH, and NY |
| Vermont Gas | 15 contractor names and phone numbers | VT |

**Data Collection**

The Navigant team completed 20 interviews for this measure, which required 74 calls having been placed. Table 5-11 summarizes the call outcomes for residential boilers. The calls were most successful when Navigant was able to get in touch with the company owner directly without having to leave a voicemail. This occurred most often at the beginning and end of the workday. The calls that did not result in successful interviews were primarily because Navigant was unable to reach the proper person.

**Table 5-11: Call Outcomes for Residential Boilers**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 20 | 27% |
| Interviews Declined | 4 | 5% |
| Unable to Reach (Did not answer or return voicemail) | 50 | 68% |
| Total | 74 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 60 data points collected from interviews with contractors, based on interviews in MA, VT, NH, RI, and upstate NY.

Several outliers in the data were identified during the analysis phase. Three material cost points were removed from the final dataset because they were more than 50 percent higher or lower than the mean cost point for a given boiler size. Occasionally, contractors had difficulty teasing apart the boiler material costs from the labor and other costs, because they only quoted their projects in terms of total cost. Navigant assumed that the outliers did not accurately represent the boiler cost.

**Results**

The incremental cost results for commercial boilers are presented in Table 5-12. The Tier 1 incremental costs represent the cost associated with the increase from 80 percent to 85 percent in thermal efficiency, and the Tier 2 incremental costs represent the cost associated with an increase from 80 percent to 90 percent. All costs are presented on a per-boiler basis. See Section 2.1 for a full explanation of the regional adjustment factors.

**Table 5-12: Residential Boiler Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (kBtu/h) | 85 AFUE | | 90 AFUE | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 50 | $501 | $501 | $1,260 | $2,153 |
| 75 | $630 | $630 | $1,388 | $2,281 |
| 105 | $784 | $784 | $1,542 | $2,435 |
| 125 | $886 | $886 | $1,645 | $2,538 |
| 150 | $1,015 | $1,015 | $1,773 | $2,666 |
| 175 | $1,143 | $1,143 | $1,902 | $2,795 |
| 200 | $1,272 | $1,272 | $2,030 | $2,923 |
| 225 | $1,400 | $1,400 | $2,159 | $3,052 |
| 250 | $1,529 | $1,529 | $2,287 | $3,180 |
| 300 | $1,785 | $1,785 | $2,544 | $3,437 |

Notes:
All costs are *incremental*; Baseline = 80% AFUE Boiler.
Total Installed Cost = Material Cost + Labor Cost (Labor = $0 for 85 AFUE efficiency level; Labor = $893 for the 90 AFUE efficiency level)

**TAG Review**

The NEEP Technical Advisor Group for residential boilers provided an informal review of the draft analysis. This was the first measure to be presented to NEEP, and this initial review helped Navigant identify points where more clarification was needed in the spreadsheets. Aside from cosmetic changes to the spreadsheet, no major revisions were made to the analysis.

**Issues for Further Research**

No major issues arose during the residential boiler analysis requiring further research.

### 5.1.3 Commercial Boilers

**Measure Specifications**

The commercial boiler analysis covers gas-fired hot water boilers with input ratings between 300 and 2,500 kBTU/H. The baseline and two high-efficiency cases were defined in terms of thermal efficiency, based on review of federal specifications and several TRMs published by NEEP sponsors and other jurisdictions, as shown in Table 5-13.

**Table 5-13: Efficiency Level Specifications for Commercial Boilers**

| Efficiency Level | Thermal Efficiency |
|---|---|
| Baseline (Federal Minimum Standard) | 80% |
| High Efficiency - Tier 1 (ENERGY STAR) | ≥ 85% |
| High Efficiency - Tier 2 | ≥ 90% |

**Data Sources**

Navigant received contact information provided by Gas Networks, National Grid, and Vermont Gas to conduct interviews with contractors. Table 5-14 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-14: NEEP-Supplied Information for Commercial Boilers**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| Gas Networks | 125 contractor names and model numbers installed | MA |
| National Grid | 115 contractor names, phone numbers, and model numbers installed | MA, RI, NH, and NY |
| Vermont Gas | 15 contractor names and phone numbers | VT |

**Data Collection**

The Navigant team completed 15 interviews for this measure, which required 76 calls having been placed. Table 5-15 summarizes the call outcomes for commercial boilers. The calls that did not result in successful interviews were primarily because Navigant was unable to reach the proper person. Compared to the residential boiler contractors, commercial contractors proved more difficult to reach, because the companies are generally larger and it was more difficult to reach the proper person. The companies that declined the interview told Navigant that they were either too busy or did not have the information needed for the interview.

**Table 5-15: Call Outcomes for Commercial Boilers**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 15 | 20% |
| Interviews Declined | 8 | 11% |
| Unable to Reach (Did not answer or return voicemail) | 53 | 70% |
| Total | 76 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 49 data points collected from interviews with contractors and 23 additional cost points from online vendors. Navigant conducted interviews in MA, VT, NH, RI, and upstate NY.

Several outliers in the data were identified during the analysis phase. Three material cost points were removed from the final dataset because they were more than 40 percent higher or lower than the mean cost point for a given boiler size. Occasionally, contractors had difficulty teasing apart the boiler material costs from the labor and other costs, and Navigant assumed that the outliers did not accurately represent the boiler cost. Navigant also identified one outlier from the estimates of incremental labor hours that was seven times higher than the mean incremental labor time, and twice as high as all other non-zero estimates. This contractor could have been pricing a much more thorough job than typical. Due to the overall consistency in the data otherwise, Navigant chose to remove the outlier from the analysis.

**Results**

The incremental cost results for commercial boilers are presented in Table 5-16. The Tier 1 incremental costs represent the cost associated with the increase from 80 percent to 85 percent in thermal efficiency, and the Tier 2 incremental costs represent the cost associated with an increase from 80 percent to 90 percent. All costs are presented on a per-boiler basis. See Section 2.1 for a full explanation of the regional adjustment factors.

**Table 5-16: Commercial Boiler Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (kBtu/h) | 85 Thermal Efficiency | | 90 Thermal Efficiency | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 300 | $625 | $625 | $2,691 | $3,305 |
| 500 | $1,385 | $1,385 | $3,450 | $4,064 |
| 700 | $2,144 | $2,144 | $4,210 | $4,823 |
| 900 | $2,903 | $2,903 | $4,969 | $5,582 |
| 1100 | $3,662 | $3,662 | $5,728 | $6,342 |
| 1300 | $4,421 | $4,421 | $6,487 | $7,101 |
| 1500 | $5,181 | $5,181 | $7,246 | $7,860 |
| 1700 | $5,940 | $5,940 | $8,006 | $8,619 |
| 2000 | $7,079 | $7,079 | $9,145 | $9,758 |
| 2200 | $7,838 | $7,838 | $9,904 | $10,517 |

Notes:
Baseline = 80% Thermal Efficiency ($E_T$) Boiler
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for 85 $E_T$ efficiency level; Incremental Labor = $614 for the 90 $E_T$ efficiency level)

**TAG Review**

The NEEP Technical Advisor Group for commercial boilers provided an informal review of the draft analysis with positive feedback about the results. The group commented that the incremental labor for Tier 1 seemed high, and upon further scrutiny, Navigant found that the incremental labor was applied to Tier 1erroneously. (The contractors that were interviewed unanimously reported that there was no incremental labor associated with Tier 1 installations.). Navigant subsequently corrected the labor analysis so that the incremental labor was applied in the Tier 2 case only. This change resulted in slightly lower overall incremental costs in the Tier 1 case. The team did not make any changes to the material analysis following the technical review.

**Issues for Further Research**

No major issues arose during the commercial boiler analysis requiring further research, other than the concern cited above, which may point to the need for further work for that program administrator to reconcile ICS with their own internal study.

### 5.1.4 Residential On-Demand Water Heater (WHS)

**Measure Specifications**

Residential on-demand water heater analysis looks at gas-fired, condensing water heaters from 30 to 65 gallons and input ratings of 180 to 199 kBtu/h. The baseline and four high-efficiency cases were defined in terms of Energy Factor (EF), based on review of federal specifications and several TRMs published by NEEP sponsors and other jurisdictions, as shown in Table 5-17. The baseline is a gas-fired storage water heater at the federal minimum standard of 58 EF. The 82 EF level is the most commonly sold efficiency level for tankless water heaters within NEEP territory, and the higher efficiency levels represent condensing models.

**Table 5-17: Efficiency Level Specifications for On-Demand WHs**

| Efficiency Level | Energy Factor |
|---|---|
| Baseline (Federal Minimum Standard) | 58 EF (Storage WH) |
| High Efficiency – Tier 1 (ENERGY STAR) | 82 EF |
| High Efficiency – Tier 2 | 94 EF |
| High Efficiency – Tier 3 | 95 EF |
| High Efficiency – Tier 4 | 96 EF |

This analysis considered two installation scenarios: 1) a standard installation where the on-demand unit replaces storage hot water heater in-kind with minimal reworking of gas and venting lines, and 2) a relocation installation where an on-demand water heater is mounted to a wall away from the original water heater location. This requires significant reworking of gas lines and venting through an exterior wall.

**Data Sources**

Navigant used contact information from Gas Networks, National Grid, and Northeast Utilities to conduct interviews with contractors. Table 5-18 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past. In some instances, Navigant interviewed contractors on more than one related measure, providing data points for multiple measures. The full set of questions was required for each measure. Given the difficulties of getting knowledgeable individuals on the phone at all, this was an economy of effort.

**Table 5-18: NEEP-Supplied Information for On-Demand WHs**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| Gas Networks | 1155 contractor names and model numbers installed* | MA |
| National Grid | 36 contractor names, phone numbers, and model numbers installed | MA, RI, NH, and NY |
| Northeast Utilities | 86 contractor names, phone numbers, and model numbers installed | CT |
| *A substantial number of names provided were those of individuals that could not be located on the Internet and were likely not contractors. | | |

**Data Collection**

Navigant called a total of 101 contractors and completed 21 interviews in the data collection process. Table 5-19 summarizes the outcomes for all calls placed for On-Demand Water Heaters (WHs). Frequently, it was difficult to reach the correct person who would be capable of providing a price quote. When possible, Navigant left a detailed message on the voicemail or with the receptionist, but rarely did the owner or technician return the call. Eleven contractors declined, typically because they did not want to disclose pricing information.

**Table 5-19: Call Outcomes for On-Demand WHs**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 21 | 21% |
| Interviews Declined | 11 | 11% |
| Unable to Reach (Did not answer or return voicemail) | 69 | 69% |
| Total | 101 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 40 data points, including six data points from online vendors. Within this data, one cost outlier was identified and therefore not used within the standard analysis. This outlier was significantly lower than all other data source costs and skewed the data downward significantly enough to warrant removing it.

**Results**

The incremental cost results for on-demand water heaters are presented in Table 5-20. The standard on-demand water heater is a non-condensing unit, which is why it is the lowest efficiency level for tankless at this time. As the units increase in efficiency factor, they become more expensive, condensing units. All costs are on a per-unit basis.

**Table 5-20: Residential Tankless Water Heater Incremental Cost Results ($/unit) – Non-Regional Specific**

| | | 82 EF | | 94 EF | |
|---|---|---|---|---|---|
| Size (kBtu/h) | Storage WH equivalent Size (Gal) | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 180 | 30 | $1,334 | $1,727 | $1,786 | $2,290 |
| 180 | 40 | $1,247 | $1,640 | $1,699 | $2,203 |
| 180 | 48 | $1,177 | $1,571 | $1,630 | $2,134 |
| 199 | 50 | $1,249 | $1,643 | $1,702 | $2,206 |
| 199 | 65 | $1,119 | $1,512 | $1,571 | $2,075 |

Notes:
Baseline = 40-gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $394 for 82 EF efficiency level; Incremental Labor = $504 for the 94 EF efficiency level)

**TAG Review**

The NEEP TAG for residential on-demand water heaters provided an informal review of the draft analysis. The TAG requested additional granularity with regard to the baseline conditions and installation methods.

For the baseline, Navigant initially established a single baseline: 40-gallon gas storage water heater with an efficiency of 0.59 EF. The TAG requested a range of baselines to reflect the various installation conditions seen in the field. As a result, Navigant included additional baselines at 30, 48, 50, and 65 gallons. These gallon sizes were the most common sizes found within tracking data provided to Navigant.

Navigant also investigated variations in installations in response to TAG comments that some on-demand water heater installations require substantial re-piping of gas and venting lines. TAG staff cited examples where existing storage water heaters are removed and on-demand water heaters are installed against an exterior wall (some distance from the original location). These installations also reroute exhaust venting through the home's sidewall instead of through a typical vertical flue. Instead of reporting an average or typical installation, the analysis distinguished two scenarios: a simple installation (same location, minimal venting/piping changes); and a relocated installation (to capture the items previously described). This resulted in two incremental labor costs that varied by approximately $360.

### 5.1.5 Residential Indirect Water Heater

**Measure Specifications**

The residential indirect hot water heater analysis covers gas-fired boilers connected to indirect hot water holding tanks with heat exchangers. The baseline is an existing residential 40-gallon hot water tank with an EF of 59. The indirect input ratings range from 40 kBtu/h to 120 kBtu/h. The baseline water heater ranges in size from 30 gallons to 65 gallons. Through analysis, all water heater tank sizes were set against the various input ratings. Table 5-21 summarizes the efficiency level definitions.

**Table 5-21: Efficiency Level Specifications for Indirect WHs**

| Efficiency Level | Definition |
|---|---|
| Baseline | 40-gal. SWH at 59 EF |
| High-efficiency level | Indirect WH installed |

**Data Sources**

Navigant received, and was able to use, contact information from Gas Networks, National Grid, and Northeast Utilities to conduct interviews with contractors. Table 5-22 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-22: NEEP-Supplied Information for Indirect WHs**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| Gas Networks | 1155 contractor names and model numbers installed* | MA |
| National Grid | 36 contractor names, phone numbers, and model numbers installed | MA, RI, NH, and NY |
| Northeast Utilities | 86 contractor names, phone numbers, and model numbers installed | CT |
| *A substantial number of names provided were those of individuals that could not be located on the Internet and were likely not contractors. | | |

**Data Collection**

Navigant called a total of 101 contractors and completed 15 interviews in the data collection process. Table 5-23 summarizes the outcomes for all calls placed for indirect hot water. Frequently, it was difficult to reach the correct person who would be capable of providing a price quote. When possible, Navigant left a detailed message on the voicemail or with the receptionist, but rarely did the owner or technician return the call. Seventeen contractors declined, typically because they did not want to disclose pricing information or did not install the indirect water heaters.

**Table 5-23: Call Outcomes for Indirect WHs**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 15 | 15% |
| Interviews Declined | 17 | 17% |
| Unable to Reach (Did not answer or return voicemail) | 69 | 69% |
| Total | 101 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 49 data points, including 18 data points from online vendors. Within this data, one cost outlier was identified and therefore not used in the standard analysis. This outlier was significantly higher than all other data source costs and skewed the data significantly enough to warrant not including it.

**Results**

The incremental cost results for indirect water heaters are presented in **Error! Reference source not found.**. The final data shows the input rating for the boiler the retrofit is connected to. This rating had the greatest impact on cost. All the data is on a per-retrofit cost, including additional materials for piping and the new hot water holding tank. See Section 4.4 for a full explanation of the regional adjustment factors.

**Table 5-24: Residential Indirect Water Heater Incremental Cost Results ($/unit) – Non-Regional Specific**

| Storage WH Size (Gal): | 30 Gal | | 40 Gal | | 50 Gal | | 65 Gal | |
|---|---|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 40 | $846 | $1,089 | $759 | $1,002 | $672 | $915 | $542 | $785 |
| 60 | $1,208 | $1,451 | $1,121 | $1,364 | $1,034 | $1,277 | $903 | $1,146 |
| 80 | $1,529 | $1,772 | $1,442 | $1,685 | $1,355 | $1,598 | $1,225 | $1,467 |
| 120 | $2,093 | $2,336 | $2,007 | $2,249 | $1,920 | $2,162 | $1,789 | $2,032 |

Notes:
Baseline = 40-gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $243 for all indirect water heater sizes)

**TAG Review**

The NEEP TAG for residential indirect water heaters provided an informal review of the draft analysis. The TAG requested additional granularity with regard to the baseline conditions similar to those comments provided for on-demand water heaters. For the baseline, Navigant initially established a single baseline: 40-gallon gas storage water heater with an efficiency of 0.59 EF. The TAG requested a range of baselines to reflect the various installation conditions seen in the field. As a result, Navigant included additional baselines at 30, 48, 50, and 65 gallons. These gallon sizes were the most common sizes found within tracking data provided to Navigant.

### 5.1.6 Residential Combination Heat/Hot Water

**Measure Specifications**

Combination Heat Hot Water units (combination units) are designed so potable water heater is within a modulating boiler unit. This measure is optimal where limited space exists for two separate units. The baseline equipment includes a standard storage tank water heater; however, this equipment is not included in the baseline equipment costs. This analysis assumes that a homeowner's boiler fails and decides to either replace the existing boiler in-kind, or opt for replacing the boiler and water heater with an efficient combination unit. Therefore, the cost to replace a water heater is excluded from a homeowner's consideration and this analysis. Because this measure accounts for two separate units, it is ranked by the Combined Appliance Efficiency. Table 5-25 summarizes the efficiency level definitions for combination units.

**Table 5-25: Efficiency Level Specifications for Combination Units**

| Efficiency Level | CAE |
|---|---|
| Baseline | Standard 80% AFUE Boiler |
| High-efficiency Tier 1 | 90 CAE |
| High-efficiency Tier 2 | 91 CAE |
| High-efficiency Tier 3 | 92 CAE |
| High-efficiency Tier 4 | 93 CAE |
| High-efficiency Tier 5 | 95 CAE |

**Data Sources**

Navigant received, and was able to use, contact information from Gas Networks, National Grid, and Northeast Utilities to conduct interviews with contractors. Table 5-26 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-26: NEEP-Supplied Information for Combination Units**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| Gas Networks | 1155* contractor names and model numbers installed | MA |
| National Grid | 36 contractor names, phone numbers, and model numbers installed | MA, RI, NH, and NY |
| Northeast Utilities | 86 contractor names, phone numbers, and model numbers installed | CT |

*A substantial number of names provided were those of individuals that could not be located on the Internet and were likely not contractors.

**Data Collection**

Navigant called a total of 101 contractors and completed a total of eight contractor interviews and seven distributor interviews. Forty-nine cost points were collected for combination equipment, including 12 Internet vendors. Baseline boiler costs were sourced from the residential boiler analysis. Table 5-27 summarizes the outcomes for all calls placed for combination heat hot water. Frequently, it was difficult to reach the correct person who would be capable of providing a price quote; while the receptionist may seem intrigued on the phone, often the owner or technician would not return our call. Twenty-five contractors declined because they did not want to disclose pricing information or did not install combination units, stating that they were "too new".

**Table 5-27: Call Outcomes for Combination Units**

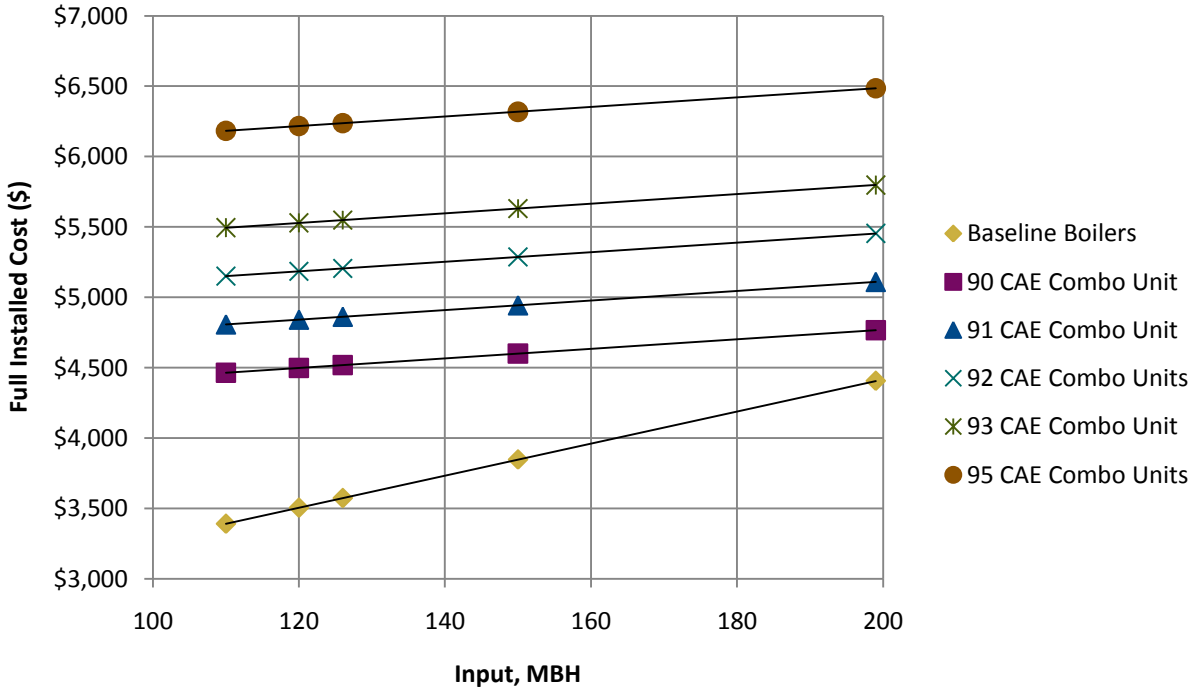
| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 15 | 14% |
| Interviews Declined | 25 | 23% |
| Unable to Reach (Did not answer or return voicemail) | 69 | 63% |
| Total | 109 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 49 data points, including 12 data points from online vendors. Within this data, three cost outliers were identified and therefore not used within the standard analysis. These outliers were significantly higher, over $10,000, than all other data source costs and skewed the data significantly enough to warrant not including it.

The incremental costs for combination units decrease as input capacity increases. This is due in part to the difference in slopes between standard boilers (the baseline units) and the combination units. Primary cost research through interviews with contractors found that for standard boilers the change in cost as input capacity increases is greater than the change in cost for combination units for the same change in input capacity. Figure 5-1 shows the converging costs as input capacity increases.

**Figure 5-1: Combination Heat and Hot Water Units Final Installed Costs**



**Results**

The incremental cost results for Combination Heat Hot Water are presented in Table 5-28. The data is presented in boiler sizes for varying efficiencies on a per-unit basis.

**Table 5-28: Residential Combination Heat/Hot Water Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (kBtu/h) | 90 CAE | | 93 CAE | | 95 CAE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 110 | $158 | $1,073 | $1,189 | $2,104 | $1,877 | $2,791 |
| 120 | $78 | $993 | $1,109 | $2,024 | $1,797 | $2,711 |
| 126 | $30 | $945 | $1,061 | $1,976 | $1,749 | $2,663 |
| 150 | -$162 | $753 | $869 | $1,784 | $1,557 | $2,471 |
| 199 | -$554 | $360 | $477 | $1,392 | $1,165 | $2,079 |

Notes:
Baseline = 80 AFUE hot water gas boiler
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $914 for all efficiency levels)

**TAG Review**

The NEEP TAG for residential combination heat/hot-water provided an informal review of the draft analysis, and during that review Navigant confirmed the installation assumptions used for the replace-on-burnout application of the measure. As described in the Measure Specification section, Navigant did not include the cost to replace a water heater in the baseline scenario. The analysis assumes that a homeowner replaces a boiler and water heater set up when the boiler fails. Therefore, the boiler is included in the baseline cost. If the water heater were to fail (while the boiler remains functional), it is assumed that a homeowner would not have the operable boiler removed to accommodate a combination system.

## *5.2 "Electric Measures"*

As noted elsewhere, in this report, the term "Electric" measure was one of convenience to distinguish between the measures initially considered by the Subcommittee and the measures proposed by the Gas Networks.

### 5.2.1 Insulation

**Measure Specifications**

Insulation analysis covers attic, wall, basement wall, and basement rim joist applications. Cellulose, fiberglass, and foam types of insulation were reviewed in this analysis. The baseline for insulation is no insulation installed or existing levels of insulation. The scenario does not have a cost consequence for any particular insulation value. A more complex scenario for insulation levels could be explored, primarily for attic insulation. Based on review of federal recommendations and several TRMs published by NEEP sponsors, efficiency levels are defined by R-value depending on the application, as shown in Table 5-29.

**Table 5-29: Efficiency Level Specifications for Insulation**

| Application | R-Value |
|---|---|
| Attic | R-19, R-38, R-60 |
| Wall | R-13, R-19, R-21 |
| Basement wall | R-16 |
| Basement rim joists | R-17 |

**Data Sources**

Navigant received contact information provided by CL&P, NYSERDA, and BG&E to conduct interviews with contractors. Table 5-30 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-30: NEEP-Supplied Information for Insulation**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| CL&P | 21 contractor names, phone numbers and model numbers installed | CT |
| NYSERDA | 244 contractor names | NY |
| BG&E | Online directory of contractor names and phone numbers | MD |

**Data Collection**

The Navigant team completed 15 interviews with 113 calls having been placed. Table 5-31 summarizes the call outcomes for insulation. The calls that did not result in successful interviews were primarily because Navigant was unable to reach the proper person. The companies that declined the interview told Navigant that they were either too busy or did not have the information needed for the interview.

**Table 5-31: Call Outcomes for Insulation**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 15 | 13% |
| Interviews Declined | 15 | 13% |
| Unable to Reach (Did not answer or return voicemail) | 83 | 74% |
| Total | 113 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. Where data was more limited, in the basement wall (basement wall was defined as below-grade or interior insulation in finished basements) and basement rim joist applications, an arithmetic mean was applied to the cost and R-value. Although average cost for basement wall and rim joist insulation is provided, data for this analysis was more limited due to low numbers of installation and limited contractor experience. Overall, the material analysis used 108 data points collected from interviews with contractors. Additionally, sprayed foam costs were found to increase at higher R-values because reaching higher values required increasing amounts of foam per unit of increase. Navigant conducted interviews in both NY and CT for insulation.

Outliers were removed from the analysis for insulation, as they were much higher or lower than other material cost points for the same R-value, application, and type. Due to many factors influencing insulation cost, including the application, type, home size, and accessibility, it was necessary to remove the 12 outliers from the analysis.

**Results**

The incremental cost results for insulation are presented in Table 5-32. Incremental cost for insulation is presented in cost per square foot. For this measure, which encompasses several insulation types, the materials and labor costs in the table were averaged. However, we have also called out the specific material and labor costs for cellulose applied in an "open blow" (no obstructions) attic. This is a very common measure scenario. The specific material and labor costs are footnoted at the end of the table.

**Table 5-32: Residential Insulation Incremental Cost Results ($/ft2) – Non-Regional Specific**

| Insulation Type | | Material Cost (averages all insulation types) | Total Installed Cost |
|---|---|---|---|
| **Attic** | **R-19** | $1.25 | $2.02* |
| | **R-38** | $1.92 | $2.69 |
| | **R-60** | $2.70 | $3.47 |
| **Wall** | **R-13** | $0.83 | $1.56 |
| | **R-19** | $1.24 | $2.02 |
| | **R-21** | $1.37 | $2.17 |
| **Basement** | **Wall (R-16)** | $1.34 | $2.93 |
| | **Rim Joist (R-17)** | $1.85 | $5.97 |

Notes:
Baseline = No Insulation
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $077/sq. ft for Attic insulation; Incremental Labor = $0.68/sq. ft for Wall insulation; Incremental Labor = $1.58/sq. ft for Basement Wall insulation; Incremental Labor = $3.20/sq. ft for Basement Rim Joist insulation)
*Open blow cellulose only Labor =$0. .36 /sq ft. Total (installed cost R19=$1.67, R38=$2.04, R60=$2.48)

**TAG Review**
The NEEP TAG for insulation provided an informal review of the draft analysis with no major issues or concerns.

**Issues for Further Research**
Some further baseline specification for attic insulation might be useful. While the baseline assumes no insulation, further scenarios for some existing insulation level could be developed. These scenarios would be climate-dependent and perhaps state or program administrator-dependent.

### 5.2.2 Air Sealing

**Measure Specifications**
The baseline and high-efficiency cases for the residential air-sealing analysis were defined in terms of air changes per hour (ACH), based on review TRMs published by NEEP sponsors and other jurisdictions[13], as shown in Table 5-33.

**Table 5-33: Efficiency Level Specifications for Air Sealing**

| Efficiency Level | ACH |
|---|---|
| Baseline (Federal Minimum Standard) | 0.50 |
| Post Air Sealing | 0.35 |

**Data Sources**
Navigant received contact information provided by CL&P and NYSERDA to conduct interviews with contractors. Navigant supplemented this contact information with others found on the Building Performance Institute (BPI) and Efficiency First websites. Table 5-34 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-34: NEEP-Supplied Information for Air-Sealing**

| Data Source | Information Supplied | States Represented |
|---|---|---|
| CL&P | 25 contractor names and phone numbers | CT |
| Efficiency First Website | 7 contractor names and phone numbers | ME |
| BPI Website | 34 contractor names and phone numbers | MD, VT |

**Data Collection**
The Navigant team completed 15 interviews for this measure, which required 76 calls having been placed. Table 5-35 summarizes the call outcomes for residential air sealing. The calls that did not result in successful interviews were primarily because Navigant was unable to reach the proper person. The

[13] Op Cit TRMs

companies that declined the interview told Navigant that they were either too busy or did not have the information needed for the interview.

**Table 5-35: Call Outcomes for Residential Air Sealing**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 18 | 19 |
| Interviews Declined | 4 | 4 |
| Unable to Reach (Did not answer or return voicemail) | 73 | 77 |
| Total | 95 | 100% |

**Analysis**

Navigant used an arithmetic mean to model material and labor costs. The analysis used 19 data points collected from interviews with contractors. Navigant conducted interviews in MA, MD, VT, CT, ME, and upstate NY.

Several outliers in the data were identified during the analysis phase. Four material cost points and four labor cost points were removed from the final dataset because they were more than 40 percent higher or lower than the mean cost point. Occasionally, contractors had difficulty teasing apart the air sealing material costs from other costs such as insulation retrofits, which were commonly conducted in conjunction with air-sealing work. These outliers may also have resulted from difficulties defining the baseline and average reductions in infiltration. Because of the fact that the baseline conditions can vary dramatically within and between regions surveyed, contractors were asked to provide an estimate of the average house size, average CFM reduced per project, and average material cost per project. As expected, estimates of average house size and CFM reduced varied widely, resulting in a range of average project cost estimates. Once outliers were removed, average project costs per square foot and per CFM reduced were applied to a range of common house sizes and reduction rates to develop the results presented below.

**Results**

The incremental cost results for residential air sealing for all regions are presented below. Table 5-36 presents the average project cost per square foot (total house size) associated with air sealing and the average project cost per CFM reduced associated with air sealing.

**Table 5-36: Residential Air-Sealing Incremental Cost Results – Non-Regional Specific**

| | Incremental Cost for 0.35 ACH | | |
|---|---|---|---|
| | **Material Cost** | **Labor Cost** | **Total Installed Cost** |
| Total Cost/ SF ($) | $0.09 | $0.36 | $0.45 |
| Total Cost/ CFM ($) | $0.25 | $0.97 | $1.21 |

Notes:
Baseline = 0.5 ACH
Total Installed Cost = Material + Labor; All costs are *incremental.*

**TAG Review**

The NEEP TAG for residential air sealing provided an informal review of the draft analysis with positive feedback about the results. NYSERDA indicated some differences with program data and found that full contracted costs for air sealing at a variety of CFM reduction intervals were higher for those projects below 500 CFM reduction and were lower for projects with greater than 500 CFM reduction for NY markets. However, NYSERDA was unable to disaggregate the full costs to determine if other costs are included and recommended no changes to NEEP results. Efficiency Vermont commented that $/cfm appear to be reasonable cost estimates.

**Issues for Further Research**

The major issue that arose during the residential air sealing analysis requiring further research was the definition of baseline conditions. A review of secondary sources found no agreement in baseline conditions, or even the metric used to measure baseline conditions. Some sources estimated costs in ACH reduced, some sources estimated cost based on time and materials, and some sources used CFM reduced as a metric for measuring infiltration reduction. Furthermore, the amount of CFM reduction that is cost-effective can vary greatly within a region and between regions. Some homes may have high rates of infiltration before air sealing, allowing for larger reductions than those with lower rates of infiltration, even though the same amount of time may be spent sealing both homes. These issues illustrate the difficulty of estimating costs for air sealing and may present areas for further research.

### 5.2.3 Residential Central AC

**Measure Specifications**

The residential central air conditioner analysis covers several sizes ranging from two to five tons capacities. The baseline and three high-efficiency cases were defined in terms of SEER rating, based on review of federal specifications, CEE tiers, ENERGY STAR rating, and several TRMs published by NEEP sponsors, as shown in Table 5-37.

**Table 5-37: Efficiency Level Specifications for Residential Central AC**

| Efficiency Level | SEER |
|---|---|
| Baseline (Federal Minimum Standard) | 13 |
| High Efficiency - Tier 1 (ENERGY STAR) | 14.5 |
| High Efficiency - Tier 2 | 15 |
| High Efficiency - Tier 3 | 16+ |

**Data Sources**

Navigant received contact information provided by National Grid, Northeast Utilities, NYSERDA, and BG&E to conduct interviews with contractors. Table 5-38 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-38: NEEP-Supplied Information for Residential Central AC**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| National Grid and Northeast Utilities | 611 contractor names, PHONE NUMBER, and model numbers installed | MA, RI, NH, and CT |
| NYSERDA | 103 contractor names | NY |
| BG&E | Online directory of contractor names and phone numbers | MD |

**Data Collection**

The Navigant team completed 19 interviews with 171 calls having been placed. Table 5-39 summarizes the call outcomes for central air conditioners. The calls that did not result in successful interviews were primarily because Navigant was unable to reach the proper person. National Grid and Northeast Utilities provided enough detailed information allowing for the collection of a greater number of cost points and a more robust data set from which a regression was applied. The companies that declined the interview told Navigant that they were either too busy or did not have the information needed for the interview. Due to the sensitive nature of some information requested, such as contractor markup, some contractors declined to participate.

**Table 5-39: Call Outcomes for Residential Central AC**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 19 | 11% |
| Interviews Declined | 23 | 13% |
| Unable to Reach (Did not answer or return voicemail) | 129 | 76% |
| Total | 171 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 102 data points collected from interviews with contractors. Navigant conducted interviews in MA, NY, RI, and MD.

Several outliers in the data were identified during the analysis phase. Four material cost points were removed from the final dataset; they were much higher or lower than the mean cost point for a given unit of the same size and SEER. Occasionally, contractors had difficulty teasing apart the AC material costs from the labor and other costs, and Navigant assumed that the outliers did not accurately represent the AC unit cost.

**Results**

The incremental cost results for residential central AC are presented in Table 5-40. See Section 4 for a full explanation of the regional adjustment factors.

**Table 5-40: Residential Central AC Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (tons) | 14.5 SEER | | 15 SEER | | 16+ SEER | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $923 | $923 | $1,164 | $1,164 | $2,367 | $2,367 |
| 3 | $1,104 | $1,104 | $1,345 | $1,345 | $2,548 | $2,548 |
| 4 | $1,285 | $1,285 | $1,526 | $1,526 | $2,729 | $2,729 |
| 5 | $1,466 | $1,466 | $1,707 | $1,707 | $2,910 | $2,910 |

Notes:
Baseline = 13 SEER
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

**TAG Review**

The NEEP TAG for residential central air conditioners provided an informal review of the draft analysis. The group showed concern over the higher incremental costs as compared to the 2010 DOE regulator cost analysis.[14] The DOE study involves the baseline moving from SEER 13 to SEER 15. The DOE cost analysis, however, assumes scaled-up manufacturing and a reduced cost environment. In addition, the study was not intended to portray the current market. Standard "vanilla" SEER 15 AC units are somewhat available through low-end manufacturers but evidence is that they are not being installed by contractors in energy efficiency programs.

**Issues for Further Research**

The issue of "bells and whistles" that do not increase efficiency but add to costs such as better controls, noise reduction, and better warranties was raised. This is an issue that could use further research by talking to distributors and manufacturers for a qualitative understanding of non-energy features typically bundled with efficiency upgrades to clarify what the features are. It would also be possible to examine program administrator invoices as a check on installers possibly providing inflated costs for this study. Navigant could quantify incremental cost for low-end products using Internet data and present it with caveats as a counterpoint to information provided from other dealers. Lastly, an examination of big box retailers, as part of the AC market, would possibly lower cost. There is a further question, however, about the participation of such low-end units. Program administrators might be able to help answer this question through an examination of their program incentive records and if possible actual invoices.

### 5.2.4 Residential Air Source Heat Pumps

**Measure Specifications**

This analysis covers residential air source heat pumps with capacities less than 65,000 Btu/h. The baseline and two high-efficiency cases were defined in terms of SEER and HSPF, based on review of federal specifications and several TRMs published by NEEP sponsors and other jurisdictions, as shown in Table 5-41.

[14] http://www1.eere.energy.gov/buildings/appliance_standards/residential/ac_central_1000_r.html

**Table 5-41: Efficiency Level Specifications for ASHPs**

| Efficiency Level | SEER | HSPF |
|---|---|---|
| Baseline (Federal Minimum Standard) | 13 | 7.7 |
| High Efficiency - Tier 1 (Energy Star) | ≥ 14.5 | ≥ 8.2 |
| High Efficiency - Tier 2 (CEE Tier 2) | ≥ 15 | ≥ 8.5 |

**Data Sources**

Navigant received contact information provided by National Grid, Northeast Utilities, NYSERDA, and BG&E to conduct interviews with contractors. Table 5-42 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-42: Program Administrator-Supplied Information for ASHPs**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| National Grid and Northeast Utilities | 430 contractor names, phone numbers, and model numbers installed | MA, RI, NH, NY and CT |
| NYSERDA | 18 contractor names | NY |
| BG&E | Online directory of contractor names and phone numbers | MD |

**Data Collection**

The Navigant team completed 13 interviews with contractors and distributors, with 79 calls having been placed. Table 5-43 summarizes the call outcomes for ASHPs. The calls that did not result in successful interviews were primarily because Navigant was unable to reach the proper person. The companies that declined the interview told Navigant that they were either too busy or did not have the information needed for the interview. Navigant found that heat pump contractors typically had quick access to pricing information for the brand(s) they installed, often for a series of sizes and efficiencies. Thus, a number of interviews resulted in 4+ cost points, with very clearly defined incremental costs. For this reason, Navigant deemed the data collected from the first 13 completed interviews to be sufficient to conduct the analysis.

**Table 5-43: Call Outcomes for ASHPs**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 13 | 16% |
| Interviews Declined | 11 | 14% |
| Unable to Reach (Did not answer or return voicemail) | 55 | 70% |
| Total | 79 | 100% |

**Analysis**
Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and a weighted average to calculate labor costs. The material analysis used 53 data points collected from interviews with contractors. Navigant conducted interviews in MA, NH, RI, CT, and MD.

Several outliers in the data were identified during the analysis phase. Three material cost points were removed from the final dataset because they were more than 50 percent higher than the mean cost point for a given heat pump size. Navigant decided that this deviation was too large to include in the analysis. In addition, four points were removed because they represented costs for ductless mini-splits, which are outside of the scope of this project.

**Results**
The incremental cost results for ASHPs are presented in Table 5-44.

**Table 5-44: Residential ASHP Incremental Cost Results ($/unit) – Non-Regional Specific**

| Size (tons) | 14.5 SEER | | 15 SEER | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $993 | $993 | $1,128 | $1,128 |
| 3 | $1,335 | $1,335 | $1,470 | $1,470 |
| 4 | $1,677 | $1,677 | $1,812 | $1,812 |
| 5 | $2,019 | $2,019 | $2,154 | $2,154 |

Notes:
Baseline = 13 SEER / 7.7 HSPF
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

**TAG Review**
TAG reviewers found the ASHP incremental costs to be within expected ranges. There was one suggestion that ASHPs might be another measure in which there is a premium product issue. Navigant did not have the opportunity to research this question.

**Issues for Further Research**
No major issues arose during the ASHP analysis requiring further research. Possible inquiry about premium pricing of efficient models.

### 5.2.5 Commercial Lighting Controls

**Measure Specifications**
Commercial Lighting Controls are categorized as daylighting control or photosensors, and various types of occupancy sensors, as well as different forms of timers for this study. The baseline was set as the lack of a control device, making the incremental cost as that of the actual cost of the device, as shown in Table 5-45.

**Table 5-45: Efficiency Level Specifications for Comm. Lighting Controls**

| Efficiency Level | Definition |
|---|---|
| Baseline | No control device installed |
| High-efficiency Cases | Photocontrol, Timer, or Occupancy Sensor installed |

**Data Sources**

Navigant received, and was able to use, contact information from Northeast Utilities to conduct interviews with contractors. Table 5-46 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-46: NEEP-Supplied Information for Comm. Lighting Controls**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| Northeast Utilities | 20 contractor names, phone numbers, and model numbers installed | CT |

**Data Collection**

Unlike some other measures there was little to no data available to the project team so a different data collection strategy was called for. Navigant called a total of 20 contractors and completed five interviews. A total of 278 cost points were collected from Internet vendors. These prices were then discussed with contractors who were able to confirm prices they use in the field. This form of data collection was a much more effective approach than to cold-call contractors, due to the specificity of the measures and the breadth of information offered on the Internet. The contractors who participated appreciated this approach, because it saved them time as well. Table 5-47 summarizes the outcomes for all calls placed for Commercial Lighting Controls.

**Table 5-47: Call Outcomes for Comm. Lighting Controls**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 5 | 25% |
| Interviews Declined | 15 | 75% |
| Unable to Reach (Did not answer or return voicemail) | 0 | 0% |
| Total | 20 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 278 data points. Within this data, three cost outliers were identified and therefore not used within the standard

analysis. These outliers were either significantly higher in price, skewing the data, or the technology did not fit the rest of the items being reviewed.

**Results**
The incremental cost results for commercial lighting controls are presented in Table 5-48. The data is presented by technology on a per-unit basis.

**Table 5-48: Commercial Lighting Controls Incremental Cost Results ($/unit) – Non-Regional Specific**

| Control Type | Material Cost | Labor Cost | Total Installed Cost |
|---|---|---|---|
| Fixed Photocontrol | $24 | $65 | $89 |
| Turn-Lock Photocontrol | $11 | $98 | $109 |
| Wired-in Photocontrol | $28 | $57 | $85 |
| Screw-in Photocontrol | $27 | $65 | $92 |
| Swivel Photocontrol | $32 | $65 | $97 |
| Button Photocontrol | $23 | $65 | $88 |
| Shorting Cap Photocontrol | $12 | $81 | $93 |
| Electronic Timer | $169 | $163 | $332 |
| Digital Timer | $83 | $135 | $218 |
| Switch Timer | $228 | $195 | $423 |
| Passive Infrared Occ. Sensor - Ceiling | $87 | $117 | $204 |
| Passive Infrared Occ. Sensor - Wall | $43 | $49 | $92 |
| Passive Infrared and Ultrasonic Occ. Sensor - Ceiling | $131 | $65 | $196 |
| Passive Infrared and Ultrasonic Occ. Sensor - Wall | $94 | $44 | $138 |

Notes:
Baseline = No Lighting Controls
Total Installed Cost = Material + Labor; All costs are *incremental.*

**TAG Review**
The measure was reviewed by the TAG. Informal comment received was that the costs were within the expected range.

**Issues for Further Research**
There were no issues for further research for this measure.

### 5.2.6 Commercial Unitary Air Conditioner

**Measure Specifications**
The commercial unitary air conditioner (UAC) analysis covers packaged, air-cooled units with input ratings between 65 and 240 MBH. The baseline and two high-efficiency cases were defined in terms of Energy Efficiency Ratio (EER), based on review of federal recommendations and TRMs published by NEEP sponsors, as shown in Table 5-49.

**Table 5-49: Efficiency Level Specifications for Unitary AC**

| Size (Btu/h) | Efficiency Level (EER) | | |
|---|---|---|---|
| | Baseline | Tier 1 | Tier 2 |
| 65,000 to 135,000 | 10.3 | 11.5 | 12 |
| 135,000 to 240,000 | 9.7 | 11.5 | 12 |
| 240,000 to 760,000 | 9.5 | 10.5 | 10.85 |

**Data Sources**

Navigant received contact information provided by CL&P, National Grid, Northeast Utilities, and BG&E to conduct interviews with contractors. Table 5-50 presents the information supplied and the states represented for each of the datasets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who have participated in member-sponsored energy efficiency programs in the past.

**Table 5-50: NEEP-Supplied Information for Unitary AC**

| NEEP Member | Information Supplied | States Represented |
|---|---|---|
| CL&P | 18 contractor names and phone numbers | CT |
| National Grid | 92 contractor names and equipment information | MA, RI, NH, and NY |
| Northeast Utilities | 18 contractor names and phone numbers | CT, MA, NH |
| BG&E | Online directory of contractor names and phone numbers | MD |

**Data Collection**

The Navigant team completed 10 interviews with 143 calls having been placed. Table 5-51 summarizes the call outcomes for unitary AC. Compared to call outcomes for other measures, unitary AC had a lower number of completed interviews as a percent of the total. This was due to an increase in the number of declined interviews.

**Table 5-51: Call Outcomes for Unitary AC**

| Call Outcome | Number of Calls Placed by Navigant | % of Total |
|---|---|---|
| Interviews Completed | 10 | 7% |
| Interviews Declined | 43 | 30% |
| Unable to Reach (Did not answer or return voicemail) | 90 | 63% |
| Total | 143 | 100% |

**Analysis**

Navigant used the standard ICS project regression analysis, as described in the methodology section, to model material costs and an arithmetic mean to calculate labor costs. The material analysis used 18 data points collected from interviews with contractors, 12 data points from the Internet, and 103 data points from a TEP 2009 cost study. Navigant conducted interviews in MA, CT, NH, RI, and MD. It was necessary to supplement primary contractor data with Internet and TEP cost study data due to difficulties in data collection, as mentioned previously.

**Results**

Incremental cost results for unitary AC are presented in Table 5-52. Efficiency levels vary by unit size. Refer back to Table 5-49**Error! Reference source not found.** for efficiencies by size and tier.

**Table 5-52: Commercial Unitary AC Incremental Cost Results ($/ton) – Non-Regional Specific**

| Size (tons) | CEE Tier 1 (11.5 EER) | | CEE Tier 2 (12 EER) | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 5.4 | $123 | $123 | $174 | $174 |
| 11.3 | $184 | $184 | $235 | $235 |
| 20.0 | $102 | $102 | $138 | $138 |

Notes:
Baseline = 10.3 EER for capacities of 65-135 tons; 9.7 EER for capacities of 135-240 tons.
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

**TAG Review**

One Technical Advisor for unitary AC provided an informal review of the draft analysis, with positive feedback received.

**Issues for Further Research**

Other than issues with data collection, no major issues arose during the unitary AC analysis requiring further research.

# 6. Key Findings and Recommendations

## *6.1 Key Findings and Recommendations*

### 6.1.1 Project Summary

The ICS developed incremental costs for 12 primary energy efficiency measures in a variety of measure sizes/capacities and efficiencies appropriate to each measure. The ICS captured both materials/equipment and labor costs, normalized them through a transparent[15] analysis process that produced NRS costs for each measure, and then using cost factors obtained from R.S. Means adjusted costs for each of six markets representing participating NEEP states and program administrators. This process provided incremental costs across these states and markets achieving economies of scale not typically achievable in incremental cost studies.

The ICS developed cost curves for each measure. For many measures these costs are scalable, so they can capture differences among measure sizes or capacities in current programs. The cost curves can also be readily extended through successive years in most cases, with supplemental interviewing to assess changes in the specific equipment. Further, program planners and other users can customize the spreadsheets to incorporate their own data such as state or local cost factors, conduct sensitivity analyses, or make other customizations to accommodate their particular needs.

### 6.1.2 Premium Measure Costs

Navigant encountered a situation that affects several types of efficient equipment and appliances, including Residential Air Conditioning and possibly Air Source Heat Pumps among the study measures. Briefly, some energy-efficient appliances and equipment are manufactured and sold as premium products. Along with higher efficiencies, such equipment may have more user-friendly or flexible controls, better warranties, and other features that may affect convenience, utility or appearance but add little or nothing to increased energy efficiency.

The premium product circumstance was clearest for Residential Air Conditioning. The baseline efficiency for this measure is Seasonal Energy Efficiency Ratio (SEER) 13. Higher efficiency models are offered with additional features that increase cost but don't add to the unit's energy efficiency; generally these premium models are the only models offered by installers who participate in the energy efficiency programs. There are some "vanilla"[16] SEER 15 units in the market but these models are mainly lower end brands. The lack of "vanilla" units could be attributable to any of several factors or a combination of factors, such as manufacturer/distributor supply requirements, installer margins(premium products typically offer more profit), installers of "vanilla" units willingness to adhere to program administrator sizing and/or quality installation requirements, perceived reliability of low end brands and other factors to be determined. There is almost certainly a cost premium to the SEER 15 units currently receiving

[15] Navigant's analysis process is transparent in that all inputs, calculations and results are provided to the Subcommittee in an open environment. There are no inaccessible "black box" calculations.

[16] "Vanilla" means products that meet a specific energy efficiency standard without additional features that may enhance convenience or appearance, adding additional cost without adding additional energy efficiency.

incentives for the non-energy efficiency features. That cost premium is bundled into the total unit cost in ways that are not transparent. However, one commenter thought that unbundling the premium costs should not be considered because consumers would be more likely to buy units with the premium features.

Energy efficiency programs are potentially affected by premium product in the following way. As standards increase, the incremental savings achievable between the baseline and the efficient increment decrease. If more efficient equipment is available only in premium products, with the smaller savings increment, the total cost per increment of savings may increase.

### 6.1.3 Measures Not Selected for Primary Research

Navigant believes that given the available existing cost data, all of the original program measure costs that were not selected for primary research would benefit from further cost research. The ICS was designed to provide robust costs for measures that would be most valuable and cost effective to research and report. Considerations of time and budget limited the number of measures for which the ICS project performed primary research. The secondary research process was therefore a winnowing process. Navigant's charge for Phase 1 was discovery and assessment of existing data rather than cost analysis. The assessment raised many concerns about the quality, consistency, timeliness and overall applicability of the existing cost data. Age was the largest single consideration and we note in that regard that the Forward Capacity Markets have adopted strict standards on study vintage. Further, inconsistent presentations of measures, materials and/or labor and other factors made it difficult to discern which studies could be considered directly comparable. For these reasons, Navigant did not provide costs in its secondary research report. The study team was concerned that doing so could be seen as an endorsement of the costs found in that phase.

Future cost work characterizing some measures that operate essentially as systems will pose challenges, mainly with respect to establishing relevant scenarios for measures that can be applied in greatly varying situations. However, with careful specification even more complex measures can be systematically estimated. Navigant believes this work is still needed.

### 6.1.4 The Importance of Technical Advisory Groups

The ICS required considerable technical expertise on the part of the research team. The study also required frequent input from on-the-ground program administrator staff and other technical experts working for Subcommittee members to ensure that measures were appropriately specified, that baselines were appropriate to the efficient measures, that the interview protocols asked the correct questions, and that the cost results squared with reality. NEEP assisted the study by recruiting and organizing technical advisors and actively seeking their input at each project stage. The advisors provided advice, and questioned some assumptions, some equipment specifications, and some results in open exchanges that were critically helpful to obtaining and ensuring robust project results.

### 6.1.5 The Importance of Project Data

Navigant's project approach focused on the specific equipment makes and models receiving incentives in current and recent program administrator programs. Obtaining such information was a significant challenge. The project team learned that most program administrators did not themselves maintain data at the necessary level of detail for this study's purposes in their own databases. In most cases, the level of

data detail needed for this study was held by program implementation contractors; even among implementers, the breadth and depth of measure and installer data varied greatly. Navigant considered an alternate approach of examining actual incentive invoices, which has been done in other studies; however, this approach was not practical among the variety of program administrators for conformance with privacy laws and other considerations.

Navigant suggests that program administrators move toward a common approach to data collected and/or extracted as a means to provide reliable data for future cost and other studies. Changing existing databases to accommodate particular needs would be formidable and expensive for program administrators and for implementation contractors. However, it may be possible to develop a common set of data extract standards to pull specific data out of implementation contractor records for needs such as updated incremental costs.

### 6.1.6 Future Joint Efforts Can Facilitate More Frequent Economical Cost Updates

Navigant and others have noted the difficulty and expense of conducting incremental cost studies and the resultant lack of good cost data at a time in which cost side of Benefit/Cost analysis is becoming more important. This study has been successful for developing costs for a group of measures across a substantial set of markets. However, if this study is an isolated effort, not followed up with some regularity, in a few years program administrators will need almost to start all over again. Navigant suggests some long-term strategies to regularize the cost update process while continuing to take advantage of economies of scale realized for the ICS:

1. Decide upon a regular cost update schedule, possibly every three to five years.
2. Concentrate research on measures that provide large percentages of portfolio program savings and where cost sensitivity is relatively high – that is B/C ratios are at the lower end of the spectrum.
3. Consider developing protocols for collecting invoice data that deal with privacy concerns and also provide a common data template.
4. Consider developing panels of distributors and installers who can be regularly polled on costs for participating measures; structure the panels to minimize gaming, through common data requests, secret shopping and/or other cross checking mechanisms.

This list is certainly not exhaustive but, Navigant hopes it will provide a context for continued effective work in this area.

## 7. References

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Vermont TRM 2010. "Technical Reference User Manual-Measure Savings Algorithms and Cost Assumptions." February 19, 2010. Efficiency Vermont; prepared by Badger, Chris.

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# 8. Appendices

A. Market by Market Tables for Each Measure:

1. Northern New England – Market 1 (NH, ME, VT)
2. Central- Southern New England – Market 2 (MA RI CT (except SW CT)
3. New England City – Market 3 (Boston, Providence)
4. New York Metro – Market 4 ( New York City, Long Island, part Westchester, SW CT)
5. New York –Balance of State- Market 5
6. Mid Atlantic (District of Columbia, DE, DC)

B. Interview Protocols

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# Appendix A. Market-Specific Results

## *A.1 Northern New England – Market 1 (NH, ME, VT)*

### Table A-1. Residential Furnace Incremental Cost Results ($/unit) – Northern New England

| Size (kBtu/h) | 90 AFUE | | 92 AFUE | | 94 AFUE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 60 | $789 | $1,049 | $907 | $1,168 | $1,026 | $1,286 |
| 70 | $799 | $1,059 | $917 | $1,178 | $1,036 | $1,296 |
| 80 | $808 | $1,069 | $927 | $1,187 | $1,046 | $1,306 |
| 90 | $818 | $1,079 | $937 | $1,197 | $1,056 | $1,316 |
| 100 | $828 | $1,088 | $947 | $1,207 | $1,066 | $1,326 |
| 120 | $848 | $1,108 | $967 | $1,227 | $1,085 | $1,345 |

Notes:
Baseline = 80% AFUE furnace
Total Installed Cost = Material Cost + $260 Labor

### Table A-2. Residential Boiler Incremental Cost Results ($/unit) – Northern New England

| Size (kBtu/h) | 85 AFUE | | 90 AFUE | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 50 | $427 | $427 | $1,072 | $1,832 |
| 75 | $536 | $536 | $1,181 | $1,941 |
| 105 | $667 | $667 | $1,312 | $2,072 |
| 125 | $754 | $754 | $1,400 | $2,160 |
| 150 | $864 | $864 | $1,509 | $2,269 |
| 175 | $973 | $973 | $1,618 | $2,378 |
| 200 | $1,082 | $1,082 | $1,728 | $2,488 |
| 225 | $1,192 | $1,192 | $1,837 | $2,597 |
| 250 | $1,301 | $1,301 | $1,946 | $2,706 |
| 300 | $1,519 | $1,519 | $2,165 | $2,925 |

Notes:
All costs are *incremental*; Baseline = 80% AFUE Boiler
Total Installed Cost = Material Cost + Labor Cost (Labor = $0 for 85 AFUE efficiency level; Labor = $760 for the 90 AFUE efficiency level)

### Table A-3. Commercial Boiler Incremental Cost Results ($/unit) – Northern New England

| Size (kBtu/h) | 85 Thermal Efficiency | | 90 Thermal Efficiency | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 300 | $532 | $532 | $2,290 | $2,812 |
| 500 | $1,178 | $1,178 | $2,936 | $3,458 |
| 700 | $1,824 | $1,824 | $3,582 | $4,104 |
| 900 | $2,470 | $2,470 | $4,228 | $4,751 |
| 1100 | $3,117 | $3,117 | $4,875 | $5,397 |
| 1300 | $3,763 | $3,763 | $5,521 | $6,043 |
| 1500 | $4,409 | $4,409 | $6,167 | $6,689 |
| 1700 | $5,055 | $5,055 | $6,813 | $7,335 |
| 2000 | $6,024 | $6,024 | $7,782 | $8,304 |
| 2200 | $6,670 | $6,670 | $8,428 | $8,950 |

Notes:
Baseline = 80% Thermal Efficiency ($E_T$) Boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for 85 $E_T$ efficiency level; Incremental Labor = $522 for the 90 $E_T$ efficiency level)

### Table A-4. Residential Tankless Water Heater Incremental Cost Results ($/unit) – Northern New England

| Size (kBtu/h) | Storage WH Size (Gal) | 82 EF | | 94 EF | |
|---|---|---|---|---|---|
| | | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 180 | 30 | $1,135 | $1,470 | $1,520 | $1,949 |
| 180 | 40 | $1,061 | $1,396 | $1,446 | $1,875 |
| 180 | 48 | $1,002 | $1,337 | $1,387 | $1,816 |
| 199 | 50 | $1,063 | $1,398 | $1,448 | $1,877 |
| 199 | 65 | $952 | $1,287 | $1,337 | $1,766 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $335 for 82 EF efficiency level; Incremental Labor = $429 for the 94 EF efficiency level)

### Table A-5. Residential Indirect Water Heater Incremental Cost Results ($/unit) – Northern New England

| | 30 Gal | | 40 Gal | | 50 Gal | | 65 Gal | |
|---|---|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 40 | $846 | $1,089 | $759 | $1,002 | $672 | $915 | $542 | $785 |
| 60 | $1,208 | $1,451 | $1,121 | $1,364 | $1,034 | $1,277 | $903 | $1,146 |
| 80 | $1,529 | $1,772 | $1,442 | $1,685 | $1,355 | $1,598 | $1,225 | $1,467 |
| 120 | $2,093 | $2,336 | $2,007 | $2,249 | $1,920 | $2,162 | $1,789 | $2,032 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $207 for all indirect water heater sizes)

### Table A-6. Residential Combination Heat/Hot Water Incremental Cost Results ($/unit) – Northern New England

| Size (kBtu/h) | 90 CAE | | 93 CAE | | 95 CAE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 110 | $135 | $913 | $1,012 | $1,790 | $1,597 | $2,375 |
| 120 | $67 | $845 | $944 | $1,722 | $1,529 | $2,307 |
| 126 | $26 | $804 | $903 | $1,681 | $1,488 | $2,266 |
| 150 | -$138 | $640 | $740 | $1,518 | $1,325 | $2,103 |
| 199 | -$471 | $307 | $406 | $1,184 | $991 | $1,769 |

Notes:
Baseline = 80 AFUE hot water gas boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $778 for all efficiency levels)

### Table A-8: Residential Insulation Incremental Cost Results ($/ft2) – Northern New England

| Insulation Type | | Material Cost (averages all insulation types) | Total Installed Cost |
|---|---|---|---|
| **Attic** | **R-19** | $1.07 | $1.72* |
| | **R-38** | $1.64 | $2.29* |
| | **R-60** | $2.30 | $2.95* |
| **Wall** | **R-13** | $0.71 | $1.28 |
| | **R-19** | $1.05 | $1.63 |
| | **R-21** | $1.17 | $1.75 |
| **Basement** | **Wall (R-16)** | $1.14 | $2.49 |
| | **Rim Joist (R-17)** | $1.58 | $4.30 |

Notes:
Baseline = No Insulation
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0.65/sq. ft for Attic insulation average all types; Incremental Labor = $0.58 /sq. ft. for Wall insulation; Incremental Labor = $1.35 /sq ft for Basement Wall insulation; Incremental Labor = $2.73 for Basement Rim Joist insulation)
*Open blow cellulose costs: Labor =$0.31 /sq ft; Total Installed cost R19=$1.42, R38=$1.74, R60=$2.11.

### Table A-7. Residential Air-Sealing Incremental Cost Results – Northern New England

| | Incremental Cost for 0.35 ACH | |
|---|---|---|
| | **Material Cost** | **Total Installed Cost** |
| Total Cost/ SF ($) | $0.08 | $0.39 |
| Total Cost/ CFM ($) | $0.22 | $1.05 |

Notes:
Baseline = 0.5 ACH
Total Installed Cost = Material + Labor; (Incremental Labor = $0.31/SF or $0.83/CFM)

### Table A-8. Residential Central AC Incremental Cost Results ($/unit) – Northern New England

| Size (tons) | 14.5 SEER | | 15 SEER | | 16+ SEER | |
|---|---|---|---|---|---|---|
| | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** |
| 2 | $785 | $785 | $990 | $990 | $2,014 | $2,014 |
| 3 | $939 | $939 | $1,144 | $1,144 | $2,168 | $2,168 |
| 4 | $1,094 | $1,094 | $1,298 | $1,298 | $2,322 | $2,322 |
| 5 | $1,248 | $1,248 | $1,452 | $1,452 | $2,476 | $2,476 |

Notes:
Baseline = 13 SEER
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-9. Residential ASHP Incremental Cost Results ($/unit) – Northern New England

| Size (tons) | 14.5 SEER | | 15 SEER | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $845 | $845 | $960 | $960 |
| 3 | $1,136 | $1,136 | $1,251 | $1,251 |
| 4 | $1,427 | $1,427 | $1,542 | $1,542 |
| 5 | $1,718 | $1,718 | $1,833 | $1,833 |

Notes:
Baseline = 13 SEER / 7.7 HSPF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-10. Commercial Lighting Controls Incremental Cost Results ($/unit) – Northern New England

| Control Type | Material Cost | Labor Cost | Total Installed Cost |
|---|---|---|---|
| Fixed Photocontrol | $29 | $76 | $105 |
| Turn-Lock Photocontrol | $13 | $115 | $128 |
| Wired-in Photocontrol | $33 | $67 | $100 |
| Screw-in Photocontrol | $32 | $76 | $108 |
| Swivel Photocontrol | $38 | $76 | $114 |
| Button Photocontrol | $27 | $76 | $103 |
| Shorting Cap Photocontrol | $14 | $96 | $110 |
| Electronic Timer | $199 | $191 | $390 |
| Digital Timer | $97 | $159 | $256 |
| Switch Timer | $268 | $229 | $497 |
| Passive Infrared Occ. Sensor - Ceiling | $102 | $138 | $239 |
| Passive Infrared Occ. Sensor - Wall | $51 | $57 | $108 |
| Passive Infrared and Ultrasonic Occ. Sensor - Ceiling | $153 | $76 | $230 |
| Passive Infrared and Ultrasonic Occ. Sensor - Wall | $110 | $51 | $162 |

Notes:
Baseline = No Lighting Controls
Total Installed Cost = Material + Labor; All costs are *incremental*

### Table A-11. Commercial Unitary AC Incremental Cost Results ($/ton) – Northern New England

| Size (tons) | CEE Tier 1 (11.5 EER) | | CEE Tier 2 (12 EER) | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 5.4 | $123 | $123 | $174 | $174 |
| 11.3 | $184 | $184 | $235 | $235 |
| 20.0 | $102 | $102 | $138 | $138 |

Notes:
Baseline = 10.3 EER for capacities of 65-135 tons; 9.7 EER for capacities of 135-240 tons.
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

## A.2 *Market-Specific Results: Central/Southern New England*

### Table A-12. Residential Furnace Incremental Cost Results ($/unit) – Central/Southern New England

| Size (kBtu/h) | 90 AFUE | | 92 AFUE | | 94 AFUE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 60 | $976 | $1,298 | $1,122 | $1,444 | $1,269 | $1,591 |
| 70 | $988 | $1,310 | $1,135 | $1,457 | $1,281 | $1,603 |
| 80 | $1,000 | $1,322 | $1,147 | $1,469 | $1,294 | $1,615 |
| 90 | $1,012 | $1,334 | $1,159 | $1,481 | $1,306 | $1,628 |
| 100 | $1,024 | $1,346 | $1,171 | $1,493 | $1,318 | $1,640 |
| 120 | $1,049 | $1,371 | $1,195 | $1,517 | $1,342 | $1,664 |

Notes:
Baseline = 80% AFUE furnace
Total Installed Cost = Material Cost + $322 Labor

### Table A-13. Residential Boiler Incremental Cost Results ($/unit) – Central/Southern New England

| Size (kBtu/h) | 85 AFUE | | 90 AFUE | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 50 | $528 | $528 | $1,326 | $2,266 |
| 75 | $663 | $663 | $1,461 | $2,401 |
| 105 | $825 | $825 | $1,623 | $2,563 |
| 125 | $933 | $933 | $1,731 | $2,672 |
| 150 | $1,068 | $1,068 | $1,867 | $2,807 |
| 175 | $1,203 | $1,203 | $2,002 | $2,942 |
| 200 | $1,339 | $1,339 | $2,137 | $3,077 |
| 225 | $1,474 | $1,474 | $2,272 | $3,212 |
| 250 | $1,609 | $1,609 | $2,407 | $3,347 |
| 300 | $1,879 | $1,879 | $2,678 | $3,618 |

Notes:
All costs are *incremental*; Baseline = 80% AFUE Boiler
Total Installed Cost = Material Cost + Labor Cost (Labor = $0 for 85 AFUE efficiency level; Labor = $940 for the 90 AFUE efficiency level)

### Table A-14. Commercial Boiler Incremental Cost Results ($/unit) – Central/Southern New England

| Size (kBtu/h) | 85 Thermal Efficiency | | 90 Thermal Efficiency | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 300 | $658 | $658 | $2,833 | $3,479 |
| 500 | $1,457 | $1,457 | $3,632 | $4,278 |
| 700 | $2,257 | $2,257 | $4,431 | $5,077 |
| 900 | $3,056 | $3,056 | $5,230 | $5,876 |
| 1100 | $3,855 | $3,855 | $6,029 | $6,675 |
| 1300 | $4,654 | $4,654 | $6,828 | $7,474 |
| 1500 | $5,453 | $5,453 | $7,628 | $8,273 |
| 1700 | $6,252 | $6,252 | $8,427 | $9,073 |
| 2000 | $7,451 | $7,451 | $9,626 | $10,271 |
| 2200 | $8,250 | $8,250 | $10,425 | $11,070 |

Notes:
Baseline = 80% Thermal Efficiency ($E_T$) Boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for 85 $E_T$ efficiency level; Incremental Labor = $646 for the 90 $E_T$ efficiency level)

### Table A-15. Residential Tankless Water Heater Incremental Cost Results ($/unit) – Central/Southern New England

| Size (kBtu/h) | Storage WH Size (Gal) | 82 EF | | 94 EF | |
|---|---|---|---|---|---|
| | | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 180 | 30 | $1,404 | $1,818 | $1,880 | $2,411 |
| 180 | 40 | $1,312 | $1,726 | $1,788 | $2,319 |
| 180 | 48 | $1,239 | $1,653 | $1,715 | $2,246 |
| 199 | 50 | $1,315 | $1,729 | $1,791 | $2,322 |
| 199 | 65 | $1,177 | $1,592 | $1,654 | $2,185 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $414 for 82 EF efficiency level; Incremental Labor = $531 for the 94 EF efficiency level)

### Table A-16. Residential Indirect Water Heater Incremental Cost Results ($/unit) – Central/Southern New England

| | 30 Gal | | 40 Gal | | 50 Gal | | 65 Gal | |
|---|---|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 40 | $891 | $1,146 | $799 | $1,055 | $708 | $963 | $570 | $826 |
| 60 | $1,271 | $1,527 | $1,180 | $1,435 | $1,088 | $1,344 | $951 | $1,207 |
| 80 | $1,609 | $1,865 | $1,518 | $1,773 | $1,426 | $1,682 | $1,289 | $1,545 |
| 120 | $2,204 | $2,459 | $2,112 | $2,368 | $2,020 | $2,276 | $1,883 | $2,139 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $256 for all indirect water heater sizes)

### Table A-17. Residential Combination Heat/Hot Water Incremental Cost Results ($/unit) – Central/Southern New England

| Size (kBtu/h) | 90 CAE | | 93 CAE | | 95 CAE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 110 | $167 | $1,129 | $1,252 | $2,214 | $1,975 | $2,938 |
| 120 | $82 | $1,045 | $1,168 | $2,130 | $1,891 | $2,853 |
| 126 | $32 | $994 | $1,117 | $2,079 | $1,841 | $2,803 |
| 150 | -$170 | $792 | $915 | $1,877 | $1,639 | $2,601 |
| 199 | -$583 | $379 | $502 | $1,465 | $1,226 | $2,188 |

Notes:
Baseline = 80 AFUE hot water gas boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $962 for all efficiency levels)

= Table A-19: Residential Insulation Incremental Cost Results ($/ft2) – Central/Southern New England

| Insulation Type | | Material Cost (averages all insulation types) | Total Installed Cost |
|---|---|---|---|
| **Attic** | **R-19** | $1.32 | $2.13* |
| | **R-38** | $2.03 | $2.83* |
| | **R-60** | $2.84 | $3.65* |
| **Wall** | **R-13** | $0.87 | $1.59 |
| | **R-19** | $1.30 | $2.02 |
| | **R-21** | $1.44 | $2.16 |
| **Basement** | **Wall (R-16)** | $1.41 | $3.08 |
| | **Rim Joist (R-17)** | $1.95 | $5.32 |

Notes:
Baseline = No Insulation
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0.81/sq. ft for Attic insulation; Incremental Labor = $0.71 /sq. ft for Wall insulation; Incremental Labor = $1.67/sq. ft for Basement Wall insulation; Incremental Labor = $3.37 /sq. ft for Basement Rim Joist insulation)
*Open blow cellulose costs: Labor =$0.38/sq ft; Total Installed cost R19=$1.76, R38=$2.15, R60=$2.61.

## Table A-18. Residential Air-Sealing Incremental Cost Results – Central/Southern New England

| | Incremental Cost for 0.35 ACH | |
|---|---|---|
| | **Material Cost** | **Total Installed Cost** |
| Total Cost/ SF ($) | $0.10 | $0.48 |
| Total Cost/ CFM ($) | $0.28 | $1.30 |

Notes:
Baseline = 0.5 ACH
Total Installed Cost = Material + Labor; (Incremental Labor = $0.38/SF or $1.03/CFM)

## Table A-19. Residential Central AC Incremental Cost Results ($/unit) – Central/Southern New England

| Size (tons) | 14.5 SEER | | 15 SEER | | 16+ SEER | |
|---|---|---|---|---|---|---|
| | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** |
| 2 | $971 | $971 | $1,225 | $1,225 | $2,491 | $2,491 |
| 3 | $1,162 | $1,162 | $1,415 | $1,415 | $2,682 | $2,682 |
| 4 | $1,353 | $1,353 | $1,606 | $1,606 | $2,872 | $2,872 |
| 5 | $1,543 | $1,543 | $1,797 | $1,797 | $3,063 | $3,063 |

Notes:
Baseline = 13 SEER
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

**Table A-20. Residential ASHP Incremental Cost Results ($/unit) – Central/Southern New England**

| Size (tons) | 14.5 SEER | | 15 SEER | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $1,046 | $1,046 | $1,188 | $1,188 |
| 3 | $1,405 | $1,405 | $1,548 | $1,548 |
| 4 | $1,765 | $1,765 | $1,908 | $1,908 |
| 5 | $2,125 | $2,125 | $2,267 | $2,267 |

Notes:
Baseline = 13 SEER / 7.7 HSPF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

**Table A-21. Commercial Lighting Controls Incremental Cost Results ($/unit) – Central/Southern New England**

| Control Type | Material Cost | Labor Cost | Total Installed Cost |
|---|---|---|---|
| Fixed Photocontrol | $30 | $80 | $111 |
| Turn-Lock Photocontrol | $14 | $121 | $135 |
| Wired-in Photocontrol | $34 | $70 | $105 |
| Screw-in Photocontrol | $34 | $80 | $114 |
| Swivel Photocontrol | $40 | $80 | $120 |
| Button Photocontrol | $28 | $80 | $109 |
| Shorting Cap Photocontrol | $15 | $101 | $115 |
| Electronic Timer | $210 | $201 | $411 |
| Digital Timer | $102 | $168 | $270 |
| Switch Timer | $282 | $241 | $523 |
| Passive Infrared Occ. Sensor - Ceiling | $107 | $145 | $252 |
| Passive Infrared Occ. Sensor - Wall | $54 | $60 | $114 |
| Passive Infrared and Ultrasonic Occ. Sensor - Ceiling | $162 | $80 | $242 |
| Passive Infrared and Ultrasonic Occ. Sensor - Wall | $116 | $54 | $170 |

Notes:
Baseline = No Lighting Controls
Total Installed Cost = Material + Labor; All costs are *incremental*

### Table A-22. Commercial Unitary AC Incremental Cost Results ($/ton) – Central/Southern New England

| Size (tons) | CEE Tier 1 (11.5 EER) | | CEE Tier 2 (12 EER) | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 5.4 | $129 | $129 | $183 | $183 |
| 11.3 | $194 | $194 | $247 | $247 |
| 20.0 | $108 | $108 | $145 | $145 |

Notes:
Baseline = 10.3 EER for capacities of 65-135 tons; 9.7 EER for capacities of 135-240 tons.
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

## A.3 *Market-Specific Results: New England City*

### Table A-23. Residential Furnace Incremental Cost Results ($/unit) – New England City

| Size (kBtu/h) | 90 AFUE | | 92 AFUE | | 94 AFUE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 60 | $1,034 | $1,374 | $1,189 | $1,530 | $1,344 | $1,685 |
| 70 | $1,046 | $1,387 | $1,202 | $1,543 | $1,357 | $1,698 |
| 80 | $1,059 | $1,400 | $1,215 | $1,556 | $1,370 | $1,711 |
| 90 | $1,072 | $1,413 | $1,228 | $1,569 | $1,383 | $1,724 |
| 100 | $1,085 | $1,426 | $1,241 | $1,582 | $1,396 | $1,737 |
| 120 | $1,111 | $1,452 | $1,266 | $1,607 | $1,422 | $1,763 |

Notes:
Baseline = 80% AFUE furnace
Total Installed Cost = Material Cost + $341 Labor

### Table A-24. Residential Boiler Incremental Cost Results ($/unit) – New England City

| Size (kBtu/h) | 85 AFUE | | 90 AFUE | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 50 | $559 | $559 | $1,404 | $2,400 |
| 75 | $702 | $702 | $1,548 | $2,544 |
| 105 | $874 | $874 | $1,719 | $2,715 |
| 125 | $988 | $988 | $1,834 | $2,830 |
| 150 | $1,132 | $1,132 | $1,977 | $2,973 |
| 175 | $1,275 | $1,275 | $2,120 | $3,116 |
| 200 | $1,418 | $1,418 | $2,264 | $3,259 |
| 225 | $1,561 | $1,561 | $2,407 | $3,403 |
| 250 | $1,704 | $1,704 | $2,550 | $3,546 |
| 300 | $1,991 | $1,991 | $2,836 | $3,832 |

Notes:
All costs are *incremental*; Baseline = 80% AFUE Boiler
Total Installed Cost = Material Cost + Labor Cost (Labor = $0 for 85 AFUE efficiency level; Labor = $996 for the 90 AFUE efficiency level)

### Table A-25. Commercial Boiler Incremental Cost Results ($/unit) – New England City

| Size (kBtu/h) | 85 Thermal Efficiency | | 90 Thermal Efficiency | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 300 | $697 | $697 | $3,001 | $3,685 |
| 500 | $1,544 | $1,544 | $3,847 | $4,531 |
| 700 | $2,390 | $2,390 | $4,694 | $5,378 |
| 900 | $3,237 | $3,237 | $5,540 | $6,224 |
| 1100 | $4,083 | $4,083 | $6,387 | $7,071 |
| 1300 | $4,930 | $4,930 | $7,233 | $7,917 |
| 1500 | $5,776 | $5,776 | $8,080 | $8,764 |
| 1700 | $6,623 | $6,623 | $8,926 | $9,610 |
| 2000 | $7,893 | $7,893 | $10,196 | $10,880 |
| 2200 | $8,739 | $8,739 | $11,043 | $11,727 |

Notes:
Baseline = 80% Thermal Efficiency ($E_T$) Boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for 85 $E_T$ efficiency level; Incremental Labor = $684 for the 90 $E_T$ efficiency level)

### Table A-26. Residential Tankless Water Heater Incremental Cost Results ($/unit) – New England City

| Size (kBtu/h) | Storage WH Size (Gal) | 82 EF | | 94 EF | |
|---|---|---|---|---|---|
| | | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 180 | 30 | $1,487 | $1,926 | $1,991 | $2,554 |
| 180 | 40 | $1,390 | $1,829 | $1,894 | $2,457 |
| 180 | 48 | $1,312 | $1,751 | $1,817 | $2,379 |
| 199 | 50 | $1,393 | $1,831 | $1,897 | $2,460 |
| 199 | 65 | $1,247 | $1,686 | $1,752 | $2,314 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $439 for 82 EF efficiency level; Incremental Labor = $562 for the 94 EF efficiency level)

### Table A-27. Residential Indirect Water Heater Incremental Cost Results ($/unit) – New England City

| | 30 Gal | | 40 Gal | | 50 Gal | | 65 Gal | |
|---|---|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 40 | $944 | $1,214 | $847 | $1,117 | $750 | $1,020 | $604 | $875 |
| 60 | $1,347 | $1,617 | $1,250 | $1,520 | $1,153 | $1,424 | $1,007 | $1,278 |
| 80 | $1,705 | $1,976 | $1,608 | $1,879 | $1,511 | $1,782 | $1,365 | $1,636 |
| 120 | $2,334 | $2,605 | $2,237 | $2,508 | $2,140 | $2,411 | $1,995 | $2,266 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $271 for all indirect water heater sizes)

### Table A-28. Residential Combination Heat/Hot Water Incremental Cost Results ($/unit) – New England City

| | 90 CAE | | 93 CAE | | 95 CAE | |
|---|---|---|---|---|---|---|
| Size (kBtu/h) | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 110 | $177 | $1,196 | $1,326 | $2,345 | $2,092 | $3,112 |
| 120 | $87 | $1,107 | $1,237 | $2,256 | $2,003 | $3,023 |
| 126 | $34 | $1,053 | $1,183 | $2,203 | $1,950 | $2,969 |
| 150 | -$180 | $839 | $969 | $1,989 | $1,736 | $2,755 |
| 199 | -$617 | $402 | $532 | $1,552 | $1,299 | $2,318 |

Notes:
Baseline = 80 AFUE hot water gas boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $1019 for all efficiency levels)

### Table A-31: Residential Insulation Incremental Cost Results ($/ft2) – New England City

| Insulation Type | | Material Cost (averages all insulation types) | Total Installed Cost |
|---|---|---|---|
| **Attic** | **R-19** | $1.40 | $2.25* |
| | **R-38** | $2.15 | $3.00* |
| | **R-60** | $3.01 | $3.01* |
| **Wall** | **R-13** | $0.93 | $1.68 |
| | **R-19** | $1.38 | $2.14 |
| | **R-21** | $1.53 | $2.29 |
| **Basement** | **Wall (R-16)** | $1.28 | $3.26 |
| | **Rim Joist (R-17)** | $2.06 | $5.64 |

Notes:
Baseline = No Insulation
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0.86 /sq. ft for Attic insulation; Incremental Labor = $0.76/sq. ft for Wall insulation; Incremental Labor = $1.99 /sq. ft for Basement Wall insulation; Incremental Labor = $3.57/sq. ft for Basement Rim Joist insulation)
*Open blow cellulose costs: Labor =$0.40 /sq ft; Total Installed cost R19=$1.86, R38=$2.27, R60=$2.77.

### Table A-29. Residential Air-Sealing Incremental Cost Results – New England City

| | Incremental Cost for 0.35 ACH | |
|---|---|---|
| | **Material Cost** | **Total Installed Cost** |
| Total Cost/ SF ($) | $0.11 | $0.51 |
| Total Cost/ CFM ($) | $0.29 | $1.38 |

Notes:
Baseline = 0.5 ACH
Total Installed Cost = Material + Labor; (Incremental Labor = $0.41/SF or $1.09/CFM)

### Table A-30. Residential Central AC Incremental Cost Results ($/unit) – New England City

| Size (tons) | 14.5 SEER | | 15 SEER | | 16+ SEER | |
|---|---|---|---|---|---|---|
| | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** |
| 2 | $1,029 | $1,029 | $1,297 | $1,297 | $2,639 | $2,639 |
| 3 | $1,231 | $1,231 | $1,499 | $1,499 | $2,841 | $2,841 |
| 4 | $1,433 | $1,433 | $1,701 | $1,701 | $3,043 | $3,043 |
| 5 | $1,635 | $1,635 | $1,903 | $1,903 | $3,245 | $3,245 |

Notes:
Baseline = 13 SEER
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-31. Residential ASHP Incremental Cost Results ($/unit) – New England City

| Size (tons) | 14.5 SEER | | 15 SEER | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $1,108 | $1,108 | $1,258 | $1,258 |
| 3 | $1,489 | $1,489 | $1,639 | $1,639 |
| 4 | $1,870 | $1,870 | $2,021 | $2,021 |
| 5 | $2,251 | $2,251 | $2,402 | $2,402 |

Notes:
Baseline = 13 SEER / 7.7 HSPF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-32. Commercial Lighting Controls Incremental Cost Results ($/unit) – New England City

| Control Type | Material Cost | Labor Cost | Total Installed Cost |
|---|---|---|---|
| Fixed Photocontrol | $32 | $85 | $117 |
| Turn-Lock Photocontrol | $15 | $128 | $143 |
| Wired-in Photocontrol | $37 | $75 | $111 |
| Screw-in Photocontrol | $36 | $85 | $121 |
| Swivel Photocontrol | $42 | $85 | $128 |
| Button Photocontrol | $30 | $85 | $115 |
| Shorting Cap Photocontrol | $16 | $107 | $122 |
| Electronic Timer | $222 | $213 | $435 |
| Digital Timer | $108 | $178 | $286 |
| Switch Timer | $299 | $256 | $554 |
| Passive Infrared Occ. Sensor - Ceiling | $97 | $131 | $227 |
| Passive Infrared Occ. Sensor - Wall | $48 | $54 | $103 |
| Passive Infrared and Ultrasonic Occ. Sensor - Ceiling | $146 | $73 | $218 |
| Passive Infrared and Ultrasonic Occ. Sensor - Wall | $105 | $49 | $153 |

Notes:
Baseline = No Lighting Controls
Total Installed Cost = Material + Labor; All costs are *incremental*

### Table A-33. Commercial Unitary AC Incremental Cost Results ($/ton) – New England City

| Size (tons) | CEE Tier 1 (11.5 EER) | | CEE Tier 2 (12 EER) | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 5.4 | $137 | $137 | $194 | $194 |
| 11.3 | $205 | $205 | $262 | $262 |
| 20.0 | $114 | $114 | $154 | $154 |

Notes:
Baseline = 10.3 EER for capacities of 65-135 tons; 9.7 EER for capacities of 135-240 tons.
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

## A.4 *Market-Specific Results: New York Metro*

### Table A-34. Residential Furnace Incremental Cost Results ($/unit) – New York Metro

| Size (kBtu/h) | 90 AFUE | | 92 AFUE | | 94 AFUE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 60 | $1,164 | $1,548 | $1,339 | $1,723 | $1,514 | $1,898 |
| 70 | $1,178 | $1,563 | $1,354 | $1,738 | $1,529 | $1,913 |
| 80 | $1,193 | $1,577 | $1,368 | $1,752 | $1,543 | $1,927 |
| 90 | $1,208 | $1,592 | $1,383 | $1,767 | $1,558 | $1,942 |
| 100 | $1,222 | $1,606 | $1,397 | $1,781 | $1,572 | $1,956 |
| 120 | $1,251 | $1,635 | $1,426 | $1,810 | $1,601 | $1,985 |

Notes:
Baseline = 80% AFUE furnace
Total Installed Cost = Material Cost + $384 Labor

### Table A-35. Residential Boiler Incremental Cost Results ($/unit) – New York Metro

| Size (kBtu/h) | 85 AFUE | | 90 AFUE | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 50 | $629 | $629 | $1,582 | $2,703 |
| 75 | $791 | $791 | $1,743 | $2,865 |
| 105 | $984 | $984 | $1,937 | $3,058 |
| 125 | $1,113 | $1,113 | $2,066 | $3,187 |
| 150 | $1,274 | $1,274 | $2,227 | $3,348 |
| 175 | $1,436 | $1,436 | $2,388 | $3,510 |
| 200 | $1,597 | $1,597 | $2,549 | $3,671 |
| 225 | $1,758 | $1,758 | $2,711 | $3,832 |
| 250 | $1,919 | $1,919 | $2,872 | $3,993 |
| 300 | $2,242 | $2,242 | $3,194 | $4,316 |

Notes:
All costs are *incremental*; Baseline = 80% AFUE Boiler
Total Installed Cost = Material Cost + Labor Cost (Labor = $0 for 85 AFUE efficiency level; Labor = $1122 for the 90 AFUE efficiency level)

### Table A-36. Commercial Boiler Incremental Cost Results ($/unit) – New York Metro

| Size (kBtu/h) | 85 Thermal Efficiency | | 90 Thermal Efficiency | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 300 | $785 | $785 | $3,379 | $4,150 |
| 500 | $1,739 | $1,739 | $4,333 | $5,103 |
| 700 | $2,692 | $2,692 | $5,286 | $6,057 |
| 900 | $3,645 | $3,645 | $6,240 | $7,010 |
| 1100 | $4,599 | $4,599 | $7,193 | $7,963 |
| 1300 | $5,552 | $5,552 | $8,146 | $8,917 |
| 1500 | $6,506 | $6,506 | $9,100 | $9,870 |
| 1700 | $7,459 | $7,459 | $10,053 | $10,824 |
| 2000 | $8,889 | $8,889 | $11,483 | $12,254 |
| 2200 | $9,842 | $9,842 | $12,437 | $13,207 |

Notes:
Baseline = 80% Thermal Efficiency ($E_T$) Boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for 85 $E_T$ efficiency level; Incremental Labor = $770 for the 90 $E_T$ efficiency level)

### Table A-37. Residential Tankless Water Heater Incremental Cost Results ($/unit) – New York Metro

| Size (kBtu/h) | Storage WH Size (Gal) | 82 EF | | 94 EF | |
|---|---|---|---|---|---|
| | | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 180 | 30 | $1,675 | $2,169 | $2,243 | $2,876 |
| 180 | 40 | $1,565 | $2,060 | $2,134 | $2,767 |
| 180 | 48 | $1,478 | $1,972 | $2,046 | $2,680 |
| 199 | 50 | $1,568 | $2,063 | $2,137 | $2,770 |
| 199 | 65 | $1,405 | $1,899 | $1,973 | $2,606 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $494 for 82 EF efficiency level; Incremental Labor = $633 for the 94 EF efficiency level)

### Table A-38. Residential Indirect Water Heater Incremental Cost Results ($/unit) – New York Metro

| | 30 Gal | | 40 Gal | | 50 Gal | | 65 Gal | |
|---|---|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 40 | $1,063 | $1,368 | $953 | $1,258 | $844 | $1,149 | $680 | $985 |
| 60 | $1,517 | $1,822 | $1,407 | $1,712 | $1,298 | $1,603 | $1,134 | $1,439 |
| 80 | $1,920 | $2,225 | $1,811 | $2,116 | $1,702 | $2,007 | $1,538 | $1,843 |
| 120 | $2,629 | $2,934 | $2,520 | $2,825 | $2,410 | $2,715 | $2,247 | $2,552 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $305 for all indirect water heater sizes)

### Table A-39. Residential Combination Heat/Hot Water Incremental Cost Results ($/unit) – New York Metro

| | 90 CAE | | 93 CAE | | 95 CAE | |
|---|---|---|---|---|---|---|
| Size (kBtu/h) | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 110 | $199 | $1,347 | $1,493 | $2,642 | $2,357 | $3,505 |
| 120 | $98 | $1,246 | $1,393 | $2,541 | $2,256 | $3,404 |
| 126 | $38 | $1,186 | $1,333 | $2,481 | $2,196 | $3,344 |
| 150 | -$203 | $945 | $1,092 | $2,240 | $1,955 | $3,103 |
| 199 | -$695 | $453 | $599 | $1,747 | $1,462 | $2,611 |

Notes:
Baseline = 80 AFUE hot water gas boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $1148 for all efficiency levels)

### Table A-43: Residential Insulation Incremental Cost Results ($/ft2) – New York Metro

| Insulation Type | | Material Cost (averages all insulation types) | Total Installed Cost |
|---|---|---|---|
| **Attic** | **R-19** | $1.57 | $2.54* |
| | **R-38** | $2.42 | $3.38* |
| | **R-60** | $3.39 | $4.36* |
| **Wall** | **R-13** | $1.04 | $1.89 |
| | **R-19** | $1.55 | $2.41 |
| | **R-21** | $1.72 | $2.58 |
| **Basement** | **Wall (R-16)** | $1.69 | $3.67 |
| | **Rim Joist (R-17)** | $2.33 | $6.35 |

Notes:
Baseline = No Insulation
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0.96/sq. ft for Attic insulation; Incremental Labor = $0.85 /sq. ft for Wall insulation; Incremental Labor = $1.99/sq. ft for Basement Wall insulation; Incremental Labor = $4.02/sq. ft for Basement Rim Joist insulation)
*Open blow cellulose costs: Labor =$0.45 /sq ft; Total Installed cost R19=$2.10, R38=$2.56, R60=$3.11.

### Table A-40. Residential Air-Sealing Incremental Cost Results – New York Metro

| | Incremental Cost for 0.35 ACH | |
|---|---|---|
| | **Material Cost** | **Total Installed Cost** |
| Total Cost/ SF ($) | $0.12 | $0.58 |
| Total Cost/ CFM ($) | $0.33 | $1.55 |

Notes:
Baseline = 0.5 ACH
Total Installed Cost = Material + Labor; (Incremental Labor = $0.46/SF or $1.23/CFM)

### Table A-41. Residential Central AC Incremental Cost Results ($/unit) – New York Metro

| | 14.5 SEER | | 15 SEER | | 16+ SEER | |
|---|---|---|---|---|---|---|
| **Size (tons)** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** |
| 2 | $1,159 | $1,159 | $1,461 | $1,461 | $2,972 | $2,972 |
| 3 | $1,386 | $1,386 | $1,689 | $1,689 | $3,199 | $3,199 |
| 4 | $1,614 | $1,614 | $1,916 | $1,916 | $3,427 | $3,427 |
| 5 | $1,841 | $1,841 | $2,143 | $2,143 | $3,654 | $3,654 |

Notes:
Baseline = 13 SEER
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-42. Residential ASHP Incremental Cost Results ($/unit) – New York Metro

| Size (tons) | 14.5 SEER | | 15 SEER | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $1,247 | $1,247 | $1,417 | $1,417 |
| 3 | $1,677 | $1,677 | $1,846 | $1,846 |
| 4 | $2,106 | $2,106 | $2,276 | $2,276 |
| 5 | $2,535 | $2,535 | $2,705 | $2,705 |

Notes:
Baseline = 13 SEER / 7.7 HSPF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-43. Commercial Lighting Controls Incremental Cost Results ($/unit) – New York Metro

| Control Type | Material Cost | Labor Cost | Total Installed Cost |
|---|---|---|---|
| Fixed Photocontrol | $36 | $96 | $132 |
| Turn-Lock Photocontrol | $17 | $144 | $161 |
| Wired-in Photocontrol | $41 | $84 | $125 |
| Screw-in Photocontrol | $40 | $96 | $136 |
| Swivel Photocontrol | $48 | $96 | $144 |
| Button Photocontrol | $34 | $96 | $130 |
| Shorting Cap Photocontrol | $18 | $120 | $138 |
| Electronic Timer | $250 | $240 | $490 |
| Digital Timer | $122 | $200 | $322 |
| Switch Timer | $337 | $288 | $624 |
| Passive Infrared Occ. Sensor - Ceiling | $128 | $173 | $300 |
| Passive Infrared Occ. Sensor - Wall | $64 | $72 | $136 |
| Passive Infrared and Ultrasonic Occ. Sensor - Ceiling | $193 | $96 | $289 |
| Passive Infrared and Ultrasonic Occ. Sensor - Wall | $139 | $64 | $203 |

Notes:
Baseline = No Lighting Controls
Total Installed Cost = Material + Labor; All costs are *incremental*

### Table A-44. Commercial Unitary AC Incremental Cost Results ($/ton) – New York Metro

| Size (tons) | CEE Tier 1 (11.5 EER) | | CEE Tier 2 (12 EER) | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 5.4 | $154 | $154 | $218 | $218 |
| 11.3 | $231 | $231 | $295 | $295 |
| 20.0 | $128 | $128 | $173 | $173 |

Notes:
Baseline = 10.3 EER for capacities of 65-135 tons; 9.7 EER for capacities of 135-240 tons.
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

## A.5 *Market-Specific Results: Upstate New York*

### Table A-45. Residential Furnace Incremental Cost Results ($/unit) – Upstate New York

| Size (kBtu/h) | 90 AFUE | | 92 AFUE | | 94 AFUE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 60 | $916 | $1,219 | $1,054 | $1,357 | $1,192 | $1,495 |
| 70 | $928 | $1,230 | $1,066 | $1,368 | $1,204 | $1,506 |
| 80 | $939 | $1,242 | $1,077 | $1,380 | $1,215 | $1,517 |
| 90 | $951 | $1,253 | $1,089 | $1,391 | $1,227 | $1,529 |
| 100 | $962 | $1,265 | $1,100 | $1,402 | $1,238 | $1,540 |
| 120 | $985 | $1,287 | $1,123 | $1,425 | $1,261 | $1,563 |

Notes:
Baseline = 80% AFUE furnace
Total Installed Cost = Material Cost + $302 Labor

### Table A-46. Residential Boiler Incremental Cost Results ($/unit) – Upstate New York

| Size (kBtu/h) | 85 AFUE | | 90 AFUE | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 50 | $496 | $496 | $1,245 | $2,129 |
| 75 | $623 | $623 | $1,372 | $2,256 |
| 105 | $775 | $775 | $1,525 | $2,408 |
| 125 | $876 | $876 | $1,626 | $2,509 |
| 150 | $1,003 | $1,003 | $1,753 | $2,636 |
| 175 | $1,130 | $1,130 | $1,880 | $2,763 |
| 200 | $1,257 | $1,257 | $2,007 | $2,890 |
| 225 | $1,384 | $1,384 | $2,134 | $3,017 |
| 250 | $1,511 | $1,511 | $2,261 | $3,144 |
| 300 | $1,765 | $1,765 | $2,515 | $3,398 |

Notes:
All costs are *incremental*; Baseline = 80% AFUE Boiler
Total Installed Cost = Material Cost + Labor Cost (Labor = $0 for 85 AFUE efficiency level; Labor = $883 for the 90 AFUE efficiency level)

### Table A-47. Commercial Boiler Incremental Cost Results ($/unit) – Upstate New York

| Size (kBtu/h) | 85 Thermal Efficiency | | 90 Thermal Efficiency | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 300 | $618 | $618 | $2,661 | $3,268 |
| 500 | $1,369 | $1,369 | $3,412 | $4,018 |
| 700 | $2,120 | $2,120 | $4,162 | $4,769 |
| 900 | $2,870 | $2,870 | $4,913 | $5,520 |
| 1100 | $3,621 | $3,621 | $5,664 | $6,270 |
| 1300 | $4,372 | $4,372 | $6,414 | $7,021 |
| 1500 | $5,122 | $5,122 | $7,165 | $7,772 |
| 1700 | $5,873 | $5,873 | $7,916 | $8,522 |
| 2000 | $6,999 | $6,999 | $9,042 | $9,648 |
| 2200 | $7,750 | $7,750 | $9,792 | $10,399 |

Notes:
Baseline = 80% Thermal Efficiency ($E_T$) Boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for 85 $E_T$ efficiency level; Incremental Labor = $607 for the 90 $E_T$ efficiency level)

### Table A-48. Residential Tankless Water Heater Incremental Cost Results ($/unit) – Upstate New York

| Size (kBtu/h) | Storage WH Size (Gal) | 82 EF | | 94 EF | |
|---|---|---|---|---|---|
| | | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 180 | 30 | $1,319 | $1,708 | $1,766 | $2,265 |
| 180 | 40 | $1,233 | $1,622 | $1,680 | $2,179 |
| 180 | 48 | $1,164 | $1,553 | $1,611 | $2,110 |
| 199 | 50 | $1,235 | $1,624 | $1,682 | $2,181 |
| 199 | 65 | $1,106 | $1,495 | $1,553 | $2,052 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $389 for 82 EF efficiency level; Incremental Labor = $499 for the 94 EF efficiency level)

### Table A-49. Residential Indirect Water Heater Incremental Cost Results ($/unit) – Upstate New York

| | 30 Gal | | 40 Gal | | 50 Gal | | 65 Gal | |
|---|---|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 40 | $837 | $1,077 | $751 | $991 | $665 | $905 | $536 | $776 |
| 60 | $1,194 | $1,434 | $1,108 | $1,348 | $1,022 | $1,262 | $893 | $1,133 |
| 80 | $1,512 | $1,752 | $1,426 | $1,666 | $1,340 | $1,580 | $1,211 | $1,451 |
| 120 | $2,070 | $2,310 | $1,984 | $2,224 | $1,898 | $2,138 | $1,769 | $2,009 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $240 for all indirect water heater sizes)

### Table A-50. Residential Combination Heat/Hot Water Incremental Cost Results ($/unit) – Upstate New York

| | 90 CAE | | 93 CAE | | 95 CAE | |
|---|---|---|---|---|---|---|
| Size (kBtu/h) | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 110 | $157 | $1,060 | $1,176 | $2,080 | $1,856 | $2,759 |
| 120 | $77 | $981 | $1,097 | $2,001 | $1,776 | $2,680 |
| 126 | $30 | $934 | $1,049 | $1,953 | $1,729 | $2,633 |
| 150 | -$160 | $744 | $860 | $1,763 | $1,539 | $2,443 |
| 199 | -$547 | $356 | $472 | $1,376 | $1,152 | $2,055 |

Notes:
Baseline = 80 AFUE hot water gas boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $904 for all efficiency levels)

### Table A-55: Residential Insulation Incremental Cost Results ($/ft2) – Upstate New York

| Insulation Type | | Material Cost (averages all insulation types) | Total Installed Cost |
|---|---|---|---|
| **Attic** | **R-19** | $1.24 | $2.00* |
| | **R-38** | $1.90 | $2.66* |
| | **R-60** | $2.67 | $3.43* |
| **Wall** | **R-13** | $0.82 | $1.49 |
| | **R-19** | $1.22 | $1.89 |
| | **R-21** | $1.36 | $2.03 |
| **Basement** | **Wall (R-16)** | $1.33 | $2.89 |
| | **Rim Joist (R-17)** | $1.83 | $5.00 |

Notes:
Baseline = No Insulation
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0.76/sq. ft for Attic insulation; Incremental Labor = $0.67 /sq. ft for Wall insulation; Incremental Labor = $1.56/sq. ft for Basement Wall insulation; Incremental Labor = $3.17/sq. ft for Basement Rim Joist insulation)
*Open blow cellulose costs: Labor =$0.36 /sq ft; Total Installed cost R19=$1.65, R38=$2.02, R60=$2.45.

### Table A-51. Residential Air-Sealing Incremental Cost Results – Upstate New York

| | Incremental Cost for 0.35 ACH | |
|---|---|---|
| | **Material Cost** | **Total Installed Cost** |
| Total Cost/ SF ($) | $0.10 | $0.46 |
| Total Cost/ CFM ($) | $0.26 | $1.22 |

Notes:
Baseline = 0.5 ACH
Total Installed Cost = Material + Labor; (Incremental Labor = $0.36/SF or $0.96/CFM)

### Table A-52. Residential Central AC Incremental Cost Results ($/unit) – Upstate New York

| | 14.5 SEER | | 15 SEER | | 16+ SEER | |
|---|---|---|---|---|---|---|
| **Size (tons)** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** |
| 2 | $913 | $913 | $1,150 | $1,150 | $2,340 | $2,340 |
| 3 | $1,092 | $1,092 | $1,329 | $1,329 | $2,519 | $2,519 |
| 4 | $1,271 | $1,271 | $1,509 | $1,509 | $2,698 | $2,698 |
| 5 | $1,450 | $1,450 | $1,688 | $1,688 | $2,877 | $2,877 |

Notes:
Baseline = 13 SEER
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-53. Residential ASHP Incremental Cost Results ($/unit) – Upstate New York

| Size (tons) | 14.5 SEER | | 15 SEER | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $982 | $982 | $1,116 | $1,116 |
| 3 | $1,320 | $1,320 | $1,454 | $1,454 |
| 4 | $1,658 | $1,658 | $1,792 | $1,792 |
| 5 | $1,996 | $1,996 | $2,130 | $2,130 |

Notes:
Baseline = 13 SEER / 7.7 HSPF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-54. Commercial Lighting Controls Incremental Cost Results ($/unit) – Upstate New York

| Control Type | Material Cost | Labor Cost | Total Installed Cost |
|---|---|---|---|
| Fixed Photocontrol | $28 | $76 | $104 |
| Turn-Lock Photocontrol | $13 | $113 | $127 |
| Wired-in Photocontrol | $32 | $66 | $98 |
| Screw-in Photocontrol | $32 | $76 | $107 |
| Swivel Photocontrol | $38 | $76 | $113 |
| Button Photocontrol | $27 | $76 | $102 |
| Shorting Cap Photocontrol | $14 | $94 | $108 |
| Electronic Timer | $197 | $189 | $386 |
| Digital Timer | $96 | $157 | $254 |
| Switch Timer | $265 | $227 | $492 |
| Passive Infrared Occ. Sensor - Ceiling | $101 | $136 | $237 |
| Passive Infrared Occ. Sensor - Wall | $50 | $57 | $107 |
| Passive Infrared and Ultrasonic Occ. Sensor - Ceiling | $152 | $76 | $227 |
| Passive Infrared and Ultrasonic Occ. Sensor - Wall | $109 | $51 | $160 |

Notes:
Baseline = No Lighting Controls
Total Installed Cost = Material + Labor; All costs are *incremental*

### Table A-55. Commercial Unitary AC Incremental Cost Results ($/ton) – Upstate New York

| Size (tons) | CEE Tier 1 (11.5 EER) | | CEE Tier 2 (12 EER) | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 5.4 | $121 | $121 | $172 | $172 |
| 11.3 | $182 | $182 | $232 | $232 |
| 20.0 | $101 | $101 | $136 | $136 |

Notes:
Baseline = 10.3 EER for capacities of 65-135 tons; 9.7 EER for capacities of 135-240 tons.
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

## A.6 *Market-Specific Results: Mid-Atlantic*

### Table A-56. Residential Furnace Incremental Cost Results ($/unit) – Mid-Atlantic

| Size (kBtu/h) | 90 AFUE | | 92 AFUE | | 94 AFUE | |
|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 60 | $848 | $1,128 | $976 | $1,256 | $1,104 | $1,384 |
| 70 | $859 | $1,139 | $987 | $1,266 | $1,114 | $1,394 |
| 80 | $870 | $1,149 | $997 | $1,277 | $1,125 | $1,405 |
| 90 | $880 | $1,160 | $1,008 | $1,288 | $1,135 | $1,415 |
| 100 | $891 | $1,171 | $1,018 | $1,298 | $1,146 | $1,426 |
| 120 | $912 | $1,192 | $1,039 | $1,319 | $1,167 | $1,447 |

Notes:
Baseline = 80% AFUE furnace
Total Installed Cost = Material Cost + $280 Labor

### Table A-57. Residential Boiler Incremental Cost Results ($/unit) – Mid-Atlantic

| Size (kBtu/h) | 85 AFUE | | 90 AFUE | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 50 | $459 | $459 | $1,153 | $1,970 |
| 75 | $576 | $576 | $1,270 | $2,088 |
| 105 | $717 | $717 | $1,411 | $2,229 |
| 125 | $811 | $811 | $1,505 | $2,323 |
| 150 | $929 | $929 | $1,623 | $2,440 |
| 175 | $1,046 | $1,046 | $1,741 | $2,558 |
| 200 | $1,164 | $1,164 | $1,858 | $2,676 |
| 225 | $1,281 | $1,281 | $1,976 | $2,793 |
| 250 | $1,399 | $1,399 | $2,093 | $2,911 |
| 300 | $1,634 | $1,634 | $2,328 | $3,146 |

Notes:
All costs are *incremental*; Baseline = 80% AFUE Boiler
Total Installed Cost = Material Cost + Labor Cost (Labor = $0 for 85 AFUE efficiency level; Labor = $817 for the 90 AFUE efficiency level)

### Table A-58. Commercial Boiler Incremental Cost Results ($/unit) – Mid-Atlantic

| Size (kBtu/h) | 85 Thermal Efficiency | | 90 Thermal Efficiency | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 300 | $572 | $572 | $2,463 | $3,025 |
| 500 | $1,267 | $1,267 | $3,158 | $3,720 |
| 700 | $1,962 | $1,962 | $3,853 | $4,414 |
| 900 | $2,657 | $2,657 | $4,548 | $5,109 |
| 1100 | $3,352 | $3,352 | $5,243 | $5,804 |
| 1300 | $4,047 | $4,047 | $5,937 | $6,499 |
| 1500 | $4,742 | $4,742 | $6,632 | $7,194 |
| 1700 | $5,436 | $5,436 | $7,327 | $7,889 |
| 2000 | $6,479 | $6,479 | $8,370 | $8,931 |
| 2200 | $7,174 | $7,174 | $9,064 | $9,626 |

Notes:
Baseline = 80% Thermal Efficiency ($E_T$) Boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for 85 $E_T$ efficiency level; Incremental Labor = $562 for the 90 $E_T$ efficiency level)

### Table A-59. Residential Tankless Water Heater Incremental Cost Results ($/unit) – Mid-Atlantic

| Size (kBtu/h) | Storage WH Size (Gal) | 82 EF | | 94 EF | |
|---|---|---|---|---|---|
| | | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 180 | 30 | $1,221 | $1,581 | $1,635 | $2,096 |
| 180 | 40 | $1,141 | $1,501 | $1,555 | $2,017 |
| 180 | 48 | $1,077 | $1,437 | $1,491 | $1,953 |
| 199 | 50 | $1,143 | $1,503 | $1,557 | $2,019 |
| 199 | 65 | $1,024 | $1,384 | $1,438 | $1,899 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $360 for 82 EF efficiency level; Incremental Labor = $462 for the 94 EF efficiency level)

### Table A-60. Residential Indirect Water Heater Incremental Cost Results ($/unit) – Mid-Atlantic

| | 30 Gal | | 40 Gal | | 50 Gal | | 65 Gal | |
|---|---|---|---|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 40 | $774 | $997 | $695 | $917 | $615 | $838 | $496 | $718 |
| 60 | $1,105 | $1,328 | $1,026 | $1,248 | $946 | $1,168 | $827 | $1,049 |
| 80 | $1,399 | $1,622 | $1,320 | $1,542 | $1,240 | $1,462 | $1,121 | $1,343 |
| 120 | $1,916 | $2,138 | $1,836 | $2,059 | $1,757 | $1,979 | $1,637 | $1,860 |

Notes:
Baseline = 40 gal Storage WH w/ 59 EF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $222 for all indirect water heater sizes)

### Table A-61. Residential Combination Heat/Hot Water Incremental Cost Results ($/unit) – Mid-Atlantic

| | 90 CAE | | 93 CAE | | 95 CAE | |
|---|---|---|---|---|---|---|
| Size (kBtu/h) | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 110 | $145 | $982 | $1,089 | $1,925 | $1,718 | $2,554 |
| 120 | $72 | $908 | $1,015 | $1,852 | $1,644 | $2,481 |
| 126 | $28 | $864 | $971 | $1,808 | $1,600 | $2,437 |
| 150 | -$148 | $689 | $796 | $1,632 | $1,425 | $2,261 |
| 199 | -$507 | $330 | $437 | $1,274 | $1,066 | $1,903 |

Notes:
Baseline = 80 AFUE hot water gas boiler
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $837 for all efficiency levels)

### Table A-67: Residential Insulation Incremental Cost Results ($/ft2) – Mid-Atlantic

| Insulation Type | | Material Cost (averages all insulation types) | Total Installed Cost |
|---|---|---|---|
| **Attic** | **R-19** | $1.15 | $1.85* |
| | **R-38** | $1.76 | $2.46* |
| | **R-60** | $2.47 | $3.18* |
| **Wall** | **R-13** | $0.76 | $1.38 |
| | **R-19** | $1.13 | $1.75 |
| | **R-21** | $1.26 | $1.88 |
| **Basement** | **Wall (R-16)** | $1.23 | $2.68 |
| | **Rim Joist (R-17)** | $1.69 | $4.63 |

Notes:
Baseline = No Insulation
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0.70/sq. ft for Attic insulation; Incremental Labor = $0.62/sq. ft for Wall insulation; Incremental Labor = $1.45/sq. ft for Basement Wall insulation; Incremental Labor = $2.93/sq. ft for Basement Rim Joist insulation)
*Open blow cellulose costs: Labor =$0.33 /sq ft; Total Installed cost R19=$1.53, R38=$1.87, R60=$2.27.

### Table A-62. Residential Air-Sealing Incremental Cost Results – Mid-Atlantic

| | Incremental Cost for 0.35 ACH | |
|---|---|---|
| | **Material Cost** | **Total Installed Cost** |
| Total Cost/ SF ($) | $0.09 | $0.42 |
| Total Cost/ CFM ($) | $0.24 | $1.13 |

Notes:
Baseline = 0.5 ACH
Total Installed Cost = Material + Labor; (Incremental Labor = $0.33/SF or $0.89/CFM)

### Table A-63. Residential Central AC Incremental Cost Results ($/unit) – Mid-Atlantic

| | 14.5 SEER | | 15 SEER | | 16+ SEER | |
|---|---|---|---|---|---|---|
| **Size (tons)** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** | **Material Cost** | **Total Installed Cost** |
| 2 | $845 | $845 | $1,065 | $1,065 | $2,166 | $2,166 |
| 3 | $1,010 | $1,010 | $1,231 | $1,231 | $2,332 | $2,332 |
| 4 | $1,176 | $1,176 | $1,396 | $1,396 | $2,498 | $2,498 |
| 5 | $1,342 | $1,342 | $1,562 | $1,562 | $2,663 | $2,663 |

Notes:
Baseline = 13 SEER
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-64. Residential ASHP Incremental Cost Results ($/unit) – Mid-Atlantic

| Size (tons) | 14.5 SEER | | 15 SEER | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 2 | $909 | $909 | $1,033 | $1,033 |
| 3 | $1,222 | $1,222 | $1,346 | $1,346 |
| 4 | $1,535 | $1,535 | $1,659 | $1,659 |
| 5 | $1,848 | $1,848 | $1,972 | $1,972 |

Notes:
Baseline = 13 SEER / 7.7 HSPF
Total Installed Cost = Material + Labor; All costs are *incremental*
(Incremental Labor = $0 for all efficiency levels)

### Table A-65. Commercial Lighting Controls Incremental Cost Results ($/unit) – Mid-Atlantic

| Control Type | Material Cost | Labor Cost | Total Installed Cost |
|---|---|---|---|
| Fixed Photocontrol | $26 | $70 | $96 |
| Turn-Lock Photocontrol | $12 | $105 | $117 |
| Wired-in Photocontrol | $30 | $61 | $91 |
| Screw-in Photocontrol | $29 | $70 | $99 |
| Swivel Photocontrol | $35 | $70 | $105 |
| Button Photocontrol | $25 | $70 | $95 |
| Shorting Cap Photocontrol | $13 | $87 | $100 |
| Electronic Timer | $182 | $175 | $357 |
| Digital Timer | $89 | $146 | $235 |
| Switch Timer | $245 | $210 | $455 |
| Passive Infrared Occ. Sensor - Ceiling | $93 | $126 | $219 |
| Passive Infrared Occ. Sensor - Wall | $47 | $52 | $99 |
| Passive Infrared and Ultrasonic Occ. Sensor - Ceiling | $140 | $70 | $210 |
| Passive Infrared and Ultrasonic Occ. Sensor - Wall | $101 | $47 | $148 |

Notes:
Baseline = No Lighting Controls
Total Installed Cost = Material + Labor; All costs are *incremental*

### Table A-66. Commercial Unitary AC Incremental Cost Results ($/ton) – Mid-Atlantic

| Size (tons) | CEE Tier 1 (11.5 EER) | | CEE Tier 2 (12 EER) | |
|---|---|---|---|---|
| | Material Cost | Total Installed Cost | Material Cost | Total Installed Cost |
| 5.4 | $112 | $112 | $159 | $159 |
| 11.3 | $168 | $168 | $215 | $215 |
| 20.0 | $94 | $94 | $126 | $126 |

Notes:
Baseline = 10.3 EER for capacities of 65-135 tons; 9.7 EER for capacities of 135-240 tons.
Total Installed Cost = Material + Labor; All costs are *incremental.*
(Incremental Labor = $0 for all efficiency levels)

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## Appendix B. ICS Measure Interview Protocols

The following pages contain the interview protocols developed for each of ICS project measures that received primary research. These protocols were used in interviews with equipment installers and distributors.

NAVIGANT

NEEP EM&V Forum
**Incremental Cost Study**
Furnace Installer Interview Protocol

Company _____ Contact Phone_____

Survey Date_____ Measures _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of standard efficiency measures for residential furnaces and the differences in cost and installation for efficient alternatives. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's sales and installations of Residential Gas Furnaces, both standard and efficient models. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

**Introduction**

"To begin, please tell us a little bit about yourself and your company."

Q1. What is your name?
Q2. What is your job title?
Q3. Please briefly describe your main work responsibilities.

Q4. Who are your primary customers – builders, other installers, direct retail to homeowners? (Get details if multiple – how much is new construction, other dealers, retail, etc.

**Equipment Sold through the program**

Q5. We're looking at _X__ installations that received rebates through the program for equipment installed by __[company name]__, and I wanted to ask you about the cost to the customer for the high efficiency equipment, and then ask what would be the cost for a lower efficiency piece of equipment from the same manufacturer. We're looking for just the cost the customer would pay for the equipment, not including installation labor. Specify whether each cost is relevant for the replacement market, the new construction market, or both.

**A.1- 1: Installed Cost Comparisons**

| High-Efficiency Model Number (from program database) | Application (Replacement or New Constr.) | High Efficiency Equipment Cost | Baseline Model Number | Baseline Model Cost |
|---|---|---|---|---|
| 1. | | | | |
| 2. | | | | |
| 3. | | | | |
| 4. | | | | |
| 5. | | | | |
| 6. | | | | |

Q6. Do these costs include a markup? If so, what is the markup?

Q7. For a given AFUE, what is the additional cost of an ECM (e.g. a 92% AFUE without ECM vs. a 92% AFUE *with* ECM)?

Q8. Now I'd like to ask about installation labor just to get a sense if it takes more time to install a high efficiency piece of equipment. I'm going to ask about the same sets of equipment we just discussed and ask if there is additional labor required to install the high efficiency machine compared to the standard efficiency machine.

**Table B-1. Labor Cost**

| High-Efficiency Model Number | Application (Replacement or New Constr.) | Additional Labor Manhours | Why is it More / Less than Standard Efficiency |
|---|---|---|---|
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |
| 6. | | | |

Q9. Do the installed cost and/or labor time required for these high-efficiency installations vary **by equipment size?** If so, specify the installed cost and labor hours for various common sizes.

Q10. Is the labor required for installations in the new construction market different from replacement installations?

Q11. For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?

a. Y / N:
   i. If No, is it High / Low:
   ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

**Equipment Sold in the past year**

Q12. In the last year, what was your breakdown in sales by AFUE? (Ask for percentages if number of installations is not known.)

**Table B-2. Sales Breakdown by AFUE**

| AFUE | Total Number of Installations | % of Total Installations |
|---|---|---|
| 80% | | |
| 85% | | |
| 90% | | |
| 92-94% | | |
| >94% | | |
| Total | | |

In the last year, what percent of your sales were:

- Single stage_____. How many of those included ECM motors_____(%)
- Multi Stage_____. How many of those included ECM motors_____(%)

Could you estimate what portion of your installations are:

a. Replacement vs. New Construction?
b. Residential vs. Commercial?

**Table B-3. Sales Breakdown by Market (in % of Total Installations)**

| | Residential | Commercial |
|---|---|---|
| Replacement | | |
| New Construction | | |

Beyond a higher AFUE, what additional features/advantages do the 90, 92, 94 and 96 AFUE units offer (longer warranties, multi-stage, quieter operation, ECM, whatever else)

**Energy Efficiency Programs & Miscellaneous comments**

"Just a few more questions, about energy efficiency programs."

Q13. Are you aware of utility/non-profit energy efficiency programs?

Q14. Our records show that __[company name]_ submitted about _X_ rebates through the program for high efficiency equipment installations. About what % of your high efficiency equipment sales does that represent? __%

Q15. With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)

Q16. Are there any other comments you would like to provide us to better understand the cost of residential furnaces?

That completes the questions I have. May I call you back at this number if I need to further clarify any of your responses?

Thanks again for your assistance with this important research.

NAVIGANT

Regional EM&V Forum
Incremental Cost Study
Boiler Installer Interview Protocol

Company _____ Contact Phone_____

Survey Date_____ Measures _____ _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of standard efficiency measures for residential gas boilers and the differences in cost and installation for efficient alternatives. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's sales and installations of Residential Gas Boilers, both standard and efficient models. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

**Introduction**

"To begin, please tell us a little bit about yourself and your company."

Q1. What is your name?

**Equipment Sold through the program**

Q2. We're looking at _X__ installations that received rebates through the program for equipment installed by __[company name]__, and I wanted to ask you about the cost to the customer for the high efficiency equipment, and then ask what would be the cost for a lower efficiency piece of equipment from the same manufacturer. We're looking for just the cost the customer would pay for the equipment, not including installation labor. Specify whether each cost is relevant for the replacement market, the new construction market, or both.

**Table B-4. Installed Cost Comparisons (Data for First Column Coming from Program Database)**

| High-Efficiency Model Number (from program database) | Application (Replacement or New Constr.) | High Efficiency Equipment Cost | Baseline Model Number | Baseline Model Cost |
|---|---|---|---|---|
| 7. | | | | |
| 8. | | | | |
| 9. | | | | |
| 10. | | | | |
| 11. | | | | |
| 12. | | | | |

Q3. Do these costs include a markup? If so, what is the markup?

Q4. Now I'd like to ask about installation labor just to get a sense if it takes more time to install a high efficiency piece of equipment. I'm going to ask about the same sets of equipment we just discussed and ask if there is additional labor required to install the high efficiency machine compared to the standard efficiency machine.

**Table B-5. Labor Cost**

| High-Efficiency Model Number | Application (Replacement or New Constr.) | Additional Labor Manhours | Why is it More / Less than Standard Efficiency |
|---|---|---|---|
| 7. | | | |
| 8. | | | |
| 9. | | | |
| 10. | | | |
| 11. | | | |
| 12. | | | |

Q5. Do the installed cost and/or labor time required for these high-efficiency installations vary **by boiler size?** If so, specify the installed cost and labor hours for the various common boiler sizes in A.1- 1 above.

Q6. Outdoor Resets

b. What fraction of your installations includes an outdoor reset (both conventional and condensing installations)?

c. What would be the additional cost (both in labor and materials) to install a boiler with an outdoor reset? Is this cost different for replacement vs. new construction?

Labor:
Materials:

Q7. For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?

a. Y / N:
   i. If No, is it High / Low:
   ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

Q8. Who is your primary distributor for this equipment? What is their contact information?

**Equipment Sold in the past year(NOTE: THESE QUESTIONS DISCONTINUED AFTER TEST INTERVIEWS AS UNECESSARY AND CONFUSING TO INSTALLERS**

Q9. In the last year, what was your breakdown in sales by AFUE? How many of your installations were above 90% AFUE vs. below? (Ask for percentages if number of installations is not known.)

**Table B-6. Sales Breakdown by AFUE**

| AFUE | Total Number of Installations | |
|---|---|---|
| | Hot-Water | Steam |
| 78% (Federal Standard) | | |
| 80-84% | | |
| 85%-90% | | |
| >90% | | |
| Total | | |

Q10. What percentage of annual installations are residential: _____%

So, the breakdown between hot-water and steam installations is:

**Table B-7. Sales Breakdown by Application and Boiler Type**

| Application | Boiler Type | Total Number of annual Installations | % of Total Installations |
|---|---|---|---|
| Replacement | Hot-Water | | |
| | Steam | | |
| New Construction | Hot-Water | | |
| | Steam | | |
| Total | | | |

**Energy Efficiency Programs & Miscellaneous comments**

"Just a few more questions"

Q11. What is your job title?

Q12. Please briefly describe your main work responsibilities.

Q13. Are you aware of utility/non-profit energy efficiency programs?

Q14. Our records show that __[company name]_ submitted about _X_ rebates through the program for high efficiency equipment installations. About what % of your high efficiency equipment sales does that represent? __%

Q15. With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)

Q16. Are there any other comments you would like to provide us to better understand the cost of residential boilers?

That completes the questions I have. May I call you back at this number if I need to further clarify any of your responses?

Thanks again for your assistance with this important research.

NAVIGANT

Regional EM&V Forum
Incremental Cost Study
Commercial Boiler Installer Interview Protocol

Company _____ Contact Phone_____

Survey Date_____ Measures _____ _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of standard efficiency measures for commercial gas boilers and the differences in cost and installation for efficient alternatives. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's sales and installations of Commercial Gas Boilers, both standard and efficient models. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

**Introduction**

"To begin, please tell us a little bit about yourself and your company."

Q17. What is your name?
Q18. What is your job title?
Q19. Please briefly describe your main work responsibilities.

Q20. Who are your primary customers – builders, other installers, direct retail? (Get details if multiple – how much is new construction, other dealers, retail, etc.

**Equipment Sold through the program**

Q21. We're looking at _X__ installations that received rebates through the program for equipment installed by __[company name]__, and I wanted to ask you about the cost to the customer for the high efficiency equipment, and then ask what would be the cost for a lower efficiency piece of equipment from the same manufacturer. We're looking for just the cost the customer would pay for the equipment, not including installation labor. Specify whether each cost is relevant for the replacement market, the new construction market, or both.

**Table B-8. Installed Cost Comparisons Data for First Column Coming from Program Database**

| High-Efficiency Model Number (from program database) | Application (Replacement or New Constr.) | High Efficiency Equipment Cost | Baseline Model Number | Baseline Model Cost |
|---|---|---|---|---|
| 13. | | | | |
| 14. | | | | |
| 15. | | | | |
| 16. | | | | |
| 17. | | | | |
| 18. | | | | |

Q22. Do these costs include a markup? If so, what is the markup?

Q23. Now I'd like to ask about installation labor just to get a sense if it takes more time to install a high efficiency piece of equipment. I'm going to ask about the same sets of equipment we just discussed and ask if there is additional labor required to install the high efficiency machine compared to the standard efficiency machine.

**Table B-9. Labor Cost**

| High-Efficiency Model Number | Application (Replacement or New Constr.) | Additional Labor Manhours | Why is it More / Less than Standard Efficiency |
|---|---|---|---|
| 13. | | | |
| 14. | | | |
| 15. | | | |
| 16. | | | |
| 17. | | | |
| 18. | | | |

Q24. Do the installed cost and/or labor time required for these high-efficiency installations vary **by boiler size?** If so, what are the key breakpoints in size, and how does the cost vary?

Q25. Do you install commercial boilers with staged or modulating burners? If so, what is the incremental cost for each compared to an on/off burner?

a. Staged:
b. Modulating:

Q26. Outdoor Resets

d. What fraction of your installations includes an outdoor reset (both conventional and condensing installations)?

e. What would be the additional cost (both in labor and materials) to install a boiler with an outdoor reset? Is this cost different for replacement vs. new construction?

Labor:
Materials:

Q27. For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?

f. Y / N:
   i. If No, is it High / Low:
   ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

**Equipment Sold in the past year**

Q28. In the last year, what was your breakdown in sales by thermal efficiency? How many of your installations were above 90% thermal efficiency vs. below? (Ask for percentages if number of installations is not known.)

**Table B-10. Sales Breakdown by Thermal Efficiency**

| Thermal Efficiency | Total Number of Installations | |
|---|---|---|
| | Hot-Water | Steam |
| 80% | | |
| 80-86% | | |
| 87%-92% | | |
| >92% | | |
| Total | | |

So, the breakdown between hot-water and steam installations is:

**Table B-11. Sales Breakdown by Application and Boiler Type**

| Application | Boiler Type | Total Number of Installations | % of Total Installations |
|---|---|---|---|
| Replacement | Hot-Water | | |
| | Steam | | |
| New Construction | Hot-Water | | |
| | Steam | | |
| Total | | | |

**Energy Efficiency Programs & Miscellaneous comments**

"Just a few more questions, about energy efficiency programs."

Q29. Are you aware of utility/non-profit energy efficiency programs?

Q30. Our records show that __[company name]_ submitted about _X_ rebates through the program for high efficiency equipment installations. About what % of your high efficiency equipment sales does that represent? __%

Q31. With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)

Q32. Are there any other comments you would like to provide us to better understand the cost of boilers?

That completes the questions I have. May I call you back at this number if I need to further clarify any of your responses?

Thanks again for your assistance with this important research.

NAVIGANT

Regional EM&V Forum
Incremental Cost Study
Combination Heat Hot Water Installer Interview Protocol
)

Company _____ Contact Phone_____

Survey Date_____ Measures _____ _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of standard efficiency measures for residential gas boilers and the differences in cost and installation for efficient alternatives. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's sales and installations of Combination Heat Hot Water, both standard and efficient models. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

**Introduction**

"To begin, please tell us a little bit about yourself and your company."

Q1. What is your name?
Q2. What is your job title?
Q3. Please briefly describe your main work responsibilities.

Q4. Who are your primary customers – builders, other installers, direct retail to homeowners? (Get details if multiple – how much is new construction, other dealers, retail, etc.

Q5. Do you offer retrofits on existing hot water heaters?

**Equipment Sold through the program**

Q6. We're looking at _X__ installations that received rebates through the program for equipment installed by __[company name]__, and I wanted to ask you about the cost to the customer for the high efficiency equipment, and then ask what would be the cost for a lower efficiency piece of equipment from the same manufacturer. We're looking for just the cost the customer would pay for the equipment, not including installation labor. Specify whether each cost is relevant for the replacement market, the new construction market, or both.

**Table B-12. Installed Cost Comparisons (Data for First Column Coming from Program Database)**

| High-Efficiency Model Number (from program database OR IF NOT AVAILABLE >90% AFUE) | High Efficiency Equipment Cost | Baseline Model (boiler<85% AFUE +Free Standing Std Gas Water heater)<br><br>NEW | Baseline Model Cost (boiler<85% AFUE +Free Standing Std Gas Water heater) REPLACEMENT |
|---|---|---|---|
| 19. | | | |
| 20. | | | |
| 21. | | | |
| 22. | | | |
| 23. | | | |
| 24. | | | |

Q7. Do these costs include a markup? If so, what is the markup?

Q8. Now I'd like to ask about installation labor just to get a sense if it takes more time to install a high efficiency piece of equipment. I'm going to ask about the same sets of equipment we just discussed and ask if there is additional labor required to install the high efficiency machine compared to the standard efficiency machine.

**Table B-13. Labor Cost**

| High-Efficiency Model Number | Application (Replacement or New Constr.) | Additional Labor Man hours | Why is it More / Less than Standard Efficiency |
|---|---|---|---|
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |
| 6. | | | |

Q9. Do the installed cost and/or labor time required for these high-efficiency installations vary **by size?** If so, specify the installed cost and labor hours for the various common Combination heat/hot water units I asked about (sizes in A.1- 1 above).

Q10. For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?

g. Y / N:

i. If No, is it High / Low:

ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

**Equipment Sold in the past year**

Q11. In the last year, what was your breakdown in sales by AFUE? How many of your installations were above 90% vs. below? (Ask for percentages if number of installations is not known.)

**Table B-14. Sales Breakdown by Efficiency**

| Efficiency (AFUE) | Total Number of Installations |
|---|---|
| | Res |
| 80-84% | |
| 85%-90% | |
| >90% | |
| Total | |

**Energy Efficiency Programs & Miscellaneous comments**

"Just a few more questions, about energy efficiency programs."

Q12. Are you aware of utility/non-profit energy efficiency programs?

Q13. Our records show that __[company name]_ submitted about _X_ rebates through the program for high efficiency equipment installations. About what % of your high efficiency equipment sales does that represent? __%

Q14. With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)

Q15. Are there any other comments you would like to provide us to better understand the cost of combination heat hot water heaters?

That completes the questions I have. May I call you back at this number if I need to further clarify any of your responses?

Thanks again for your assistance with this important research.

NAVIGANT

Regional EM&V Forum
Incremental Cost Study
Indirect Hot Water Installer Interview Protocol

Company _____ Contact Phone_____

Survey Date_____ Measures _____ _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of standard efficiency measures for residential gas indirect hot water heaters and the differences in cost and installation for efficient alternatives. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's sales and installations of Indirect Water Heaters, both standard and efficient models. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

**Introduction**

"To begin, please tell us a little bit about yourself and your company."

Q1. What is your name?
Q2. What is your job title?
Q3. Please briefly describe your main work responsibilities.

Q4. Who are your primary customers – builders, other installers, direct retail to homeowners? (Get details if multiple – how much is new construction, other dealers, retail, etc.

**Equipment Sold through the program**

Q5. We're looking at _X__ installations that received rebates through the program for equipment installed by __[company name]__, and I wanted to ask you about the cost to the customer for the high efficiency equipment, and then ask what would be the cost for an indirect storage water heater compared to a free standing gas condensing water heater with an Energy Factor of .80 from the same manufacturer? We're looking for just the cost the customer would pay for the equipment, not including installation labor. Specify whether each cost is relevant for the replacement market, the new construction market, or both.

Q6.

**Table B-15. Installed Cost Comparisons Data for First Column Coming from Program Database**

| High-Efficiency Model Number (from program database –IF MODEL NOT AVAILABLE MOST COMMON .85-90+ CAE INDIRECT UNITS SOLD | High Efficiency Equipment Cost<br><br>NEW | High Efficiency Equipment Cost<br><br>Replaces std efficiency gas free standing | Condensing Gas Water Heater with .80 E.F. Cost<br>NEW | Condensing Gas Water Heater with .80 E.F. Cost<br>Replaces std efficiency gas free standing |
|---|---|---|---|---|
| 25. | | | | |
| 26. | | | | |
| 27. | | | | |
| 28. | | | | |
| 29. | | | | |
| 30. | | | | |

Q7. Do these costs include a markup? If so, what is the markup?

Q8. Now I'd like to ask about installation labor just to get a sense if it takes more time to install a high efficiency piece of equipment. I'm going to ask about the same sets of equipment we just discussed and ask if there is additional labor required to install the high efficiency machine compared to the standard efficiency machine.

**Table B-16. Labor Cost**

| High-Efficiency Model Number –IF MODEL NOT AVAILABLE MOST COMMON .85-.90+ CAE INDIRECT UNITS | Application (Replacement or New Constr.) | Additional Labor Manhours | Why is it More / Less than .80- EF condensing water heater<br><br>New | Why is it More / Less than Standard Efficiency<br><br>Replacement |
|---|---|---|---|---|
| 1. | | | | |
| 2. | | | | |
| 3. | | | | |
| 4. | | | | |
| 5. | | | | |
| 6. | | | | |

Q9. Do the installed cost and/or labor time required for these high-efficiency installations vary **by size?** If so, specify the installed cost and labor hours for the various common indirect hot water heaters I just asked about (inA.1- 1 above).

Q10. For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?

h. Y / N:

i. If No, is it High / Low:

ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

**Equipment Sold in the past year**

Q11. In the last year, what was your breakdown in Indirect Water Heater sales (Ask for percentages if number of installations is not known.)

**Table B-17. Sales Breakdown by CAE (Combined Appliance Efficiency)**

| CAE | Total Number of Installations | |
|---|---|---|
| | Res | |
| . 80-.84 | | |
| .85-.90 | | |
| >.90 | | |
| Total | | |

**Table B-18. Sales Breakdown by Application and Size**

| Application | Total Number of Installations | % of Total Installations |
|---|---|---|
| Replacement | | |
| | | |
| New Construction | | |
| | | |
| **Totals** | | |

**Energy Efficiency Programs & Miscellaneous comments**

"Just a few more questions, about energy efficiency programs."

Q12. Are you aware of utility/non-profit energy efficiency programs?

Q13. Our records show that __[company name]_ submitted about _X_ rebates through the program for high efficiency equipment installations. About what % of your high efficiency equipment sales does that represent? __%

Q14. With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)

Q15. Are there any other comments you would like to provide us to better understand the cost of indirect water heaters?

That completes the questions I have. May I call you back at this number if I need to further clarify any of your responses?

Thanks again for your assistance with this important research.

NAVIGANT

Regional EM&V Forum
Incremental Cost Study
Central Air-Conditioner Installer Interview Protocol

Company _____ Contact Phone_____

Survey Date_____ Measures _____ _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of standard efficiency measures for residential central air-conditioners and the differences in cost and installation for efficient alternatives. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's sales and installations of residential central air-conditioners, both standard and efficient models. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

**Introduction**

"To begin, please tell us a little bit about yourself and your company."

Q1. What is your name?
Q2. What is your job title?

Q3. Please briefly describe your main work responsibilities.

**Equipment Sold through the program**

Q4. We're looking at _X__ installations that received rebates through the program for equipment installed by __[company name]__, and I wanted to ask you about the cost to the customer for the high efficiency equipment, and then ask what would be the cost for a lower efficiency piece of equipment from the same manufacturer. We're looking for just the cost the customer would pay for the equipment, not including installation labor. Specify whether each cost is relevant for the replacement market, the new construction market, or both.

**Table B-19. Installed Cost Comparisons (Data for First Column Coming From Program Database)**

| Hi-Eff Model Number (from program database) | Size (tons) | SEER | Hi-Eff Equipment Cost NEW Construction | Hi-Eff Equipment Cost Replacement Unit | Baseline Model Number | Baseline Model Cost |
|---|---|---|---|---|---|---|
| 31. | | | | | | |
| 32. | | | | | | |
| 33. | | | | | | |
| 34. | | | | | | |
| 35. | | | | | | |
| 36. | | | | | | |

Q5. Do these costs include a markup? If so, what is the markup?

Q6. Now I'd like to ask about installation labor just to get a sense if it takes more time to install a high efficiency piece of equipment. I'm going to ask about the same sets of equipment we just discussed and ask if there is additional labor required to install the high efficiency machine compared to the standard efficiency machine.

**Table B-20. Labor Cost**

| High-Efficiency Model Number | Application (Replacement or New Constr.) | Additional Labor Manhours | Why is it More / Less than Standard Efficiency |
|---|---|---|---|
| 19. | | | |
| 20. | | | |
| 21. | | | |
| 22. | | | |
| 23. | | | |
| 24. | | | |

Q7. For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?

i. Y / N:

i. If No, is it High / Low:

ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

**Energy Efficiency Programs & Miscellaneous comments**

"Just a few more questions"

Q8. Are you aware of utility/non-profit energy efficiency programs?

Q9. Our records show that __[company name]_ submitted about _X_ rebates through the program for high efficiency equipment installations. About what % of your high efficiency equipment sales does that represent? __%

Q10. Are there any other comments you would like to provide us to better understand the cost of residential central air-conditioners?

That completes the questions I have. May I call you back at this number if I need to further clarify any of your responses?

Thanks again for your assistance with this important research.

NAVIGANT

Regional EM&V Forum
Incremental Cost Study
Unitary HVAC Installer Interview Protocol

Company _____ Contact Phone_____

Survey Date_____ Measures _____ _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of standard efficiency measures for unitary AC and the differences in cost and installation for efficient alternatives. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's sales and installations of Unitary HVAC, both standard and efficient models. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

**Introduction**

"To begin, please tell us a little bit about yourself and your company."

Q33. What is your name?
Q34. What is your job title?
Q35. Please briefly describe your main work responsibilities.

Q36. Who are your primary customers – builders, other installers, direct retail to homeowners? (Get details if multiple – how much is new construction, other dealers, retail, etc.

**Equipment Sold through the program**

Q37. We're looking at _X__ installations that received rebates through the program for equipment installed by __[company name]__, and I wanted to ask you about the cost to the customer for the high efficiency equipment, and then ask what would be the cost for a lower efficiency piece of equipment from the same manufacturer. We're looking for just the cost the customer would pay for the equipment, not including installation labor. Specify whether each cost is relevant for the replacement market, the new construction market, or both.

**Table B-21. Installed Cost Comparisons Data for First Column Coming from Program Database**

| High-Efficiency Model Number (from program database IF NOT AVAILABLE .82 EF) | High Efficiency Equipment Cost | Baseline Model Efficiency (13 SEER) | Baseline Model Cost (13 SEER) |
|---|---|---|---|
| 37. | | | |
| 38. | | | |
| 39. | | | |
| 40. | | | |
| 41. | | | |
| 42. | | | |

Q38. Do these costs include a markup? If so, what is the markup?

Q39. Now I'd like to ask about installation labor just to get a sense if it takes more time to install a high efficiency piece of equipment. I'm going to ask about the same sets of equipment we just discussed and ask if there is additional labor required to install the high efficiency machine compared to the standard efficiency machine.

**Table B-22. Labor Cost**

| High-Efficiency Model Number | Application New | Application Replacement | Additional Labor Manhours | Why is it More / Less than Standard Efficiency |
|---|---|---|---|---|
| 1. | | | | |
| 2. | | | | |
| 3. | | | | |
| 4. | | | | |
| 5. | | | | |
| 6. | | | | |

Q40. Do the installed cost and/or labor time required for these high-efficiency installations vary **by size?** If so, specify the installed cost and labor hours for the common AC in A.1- 1 above.

Q41. For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?

j. Y / N:

i. If No, is it High / Low:

ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

**Equipment sold in the past year**

Q42. In the last year, what was your breakdown in sales by SEER/EER?

**Table B-23. Sales Breakdown by Efficiency**

| SEER | | EER | |
|---|---|---|---|
| 14 | | 12 | |
| 15 | | 13 | |
| 16 | | 14 | |
| 17 | | 15 | |
| 18 | | 16 | |
| 19 | | 17 | |
| 20 | | 18 | |

**Table B-24. Sales Breakdown by Application**

| Application | Total Number of Installations | % of Total Installations |
|---|---|---|
| Replacement | | |
| | | |
| New Construction | | |
| | | |
| Total | | |

**Energy Efficiency Programs & Miscellaneous comments**

"Just a few more questions, about energy efficiency programs."

Q43. Are you aware of utility/non-profit energy efficiency programs?

Q44. Our records show that __[company name]_ submitted about _X_ rebates through the program for high efficiency equipment installations. About what % of your high efficiency equipment sales does that represent? __%

Q45. With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)

Q46. Are there any other comments you would like to provide us to better understand the cost of unitary HVAC?

That completes the questions I have. May I call you back at this number if I need to further clarify any of your responses?

Thanks again for your assistance with this important research.

NAVIGANT

Regional EM&V Forum
Incremental Cost Study
Air-Source Heat Pump Installer Interview Protocol

Company _____ Contact Phone_____

Survey Date_____ Measures _____ _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of standard efficiency measures for residential air-source heat pumps and the differences in cost and installation for efficient alternatives. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's sales and installations of residential air-source heat pumps, both standard and efficient models. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

**Introduction**

"To begin, please tell us a little bit about yourself and your company."

Q17. What is your name?
Q18. What is your job title?

Q19. Please briefly describe your main work responsibilities.

**Equipment Sold through the program**

Q20. We're looking at _X__ installations that received rebates through the program for equipment installed by __[company name]__, and I wanted to ask you about the cost to the customer for the high efficiency equipment, and then ask what would be the cost for a lower efficiency piece of equipment from the same manufacturer. We're looking for just the cost the customer would pay for the equipment, not including installation labor. Specify whether each cost is relevant for the replacement market, the new construction market, or both.

**Table B-25. Installed Cost Comparisons (Data for First Column Coming from Program Database)**

| Hi-Eff Model Number (from program database) | Size (tons) | SEER | HSPF | Condenser Equipment Cost | Air Handler Equipment Cost | Baseline Model Number (SEER 13/ HSPF 7.7) | Baseline Equipment Cost |
|---|---|---|---|---|---|---|---|
| 43. | | | | | | | |
| 44. | | | | | | | |
| 45. | | | | | | | |
| 46. | | | | | | | |
| 47. | | | | | | | |
| 48. | | | | | | | |

Q21. Do these costs include a markup? If so, what is the markup?
Q22. Are the incremental costs identified above roughly equivalent for split systems or packaged systems? Y/N
  a. If No, how do the incremental costs vary between split systems and packaged systems?

Q23. Now I'd like to ask about installation labor just to get a sense if it takes more time to install a high efficiency piece of equipment. I'm going to ask about the same sets of equipment we just discussed and ask if there is additional labor required to install the high efficiency unit compared to the standard efficiency machine.

**Table B-26. Labor Cost**

| High-Efficiency Model Number | Application (Replacement or New Constr.) | Additional Labor Manhours | Why is it More / Less than Standard Efficiency |
|---|---|---|---|
| 25. | | | |
| 26. | | | |
| 27. | | | |
| 28. | | | |
| 29. | | | |
| 30. | | | |

Q24. What is the variation in labor cost between split systems and packaged systems?

Q25. For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?

a. Y / N:

i. If No, is it High / Low:

ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

Q26. Is the labor required for installations in the new construction market different from replacement installations?

**Equipment Sold in the past year**

Q27. In the last year, what was your breakdown in Residential sales by SEER? (Ask for percentages if number of installations is not known.)

**Table B-27. Sales Breakdown by SEER**

| SEER | Total Number of Annual Installations (or % of total) | |
|---|---|---|
| | Split-System | Packaged |
| Federal Standard (13) | | |
| Energy Star/ CEE Tier 1 (14.5 SS/14 PK) | | |
| CEE Tier 2&3 (15/14 or higher) | | |
| >20 | | |
| Total | | |

Q28. What is the range of HSPF levels on the equipment you install? Do you install certain key SEER/HSPF pairings, or does HSPF vary independently? [Fill in table if applicable.]

**Table B-28. Sales Breakdown by HSPF**

| SEER | Total Number of Annual Installations (or % of total) | |
|---|---|---|
| | Split-System | Packaged |
| Federal Standard (<7.7 SS/8.0 PK) | | |
| Energy Star (8.2 SS/8.0 PK) | | |
| CEE Tier 2 (>8.5 SS/>8.0 PK) | | |
| Above 9.0 | | |
| Total | | |

Q29. Of those, how many are replacement installations? How many are for new construction? [Fill in table below.]

**Table B-29. Sales Breakdown by Application and Type**

| Application | Total Number of Annual Installations (or % of total) | |
|---|---|---|
| | Split-System | Packaged |
| Replacement | | |
| New Construction | | |
| Total | | |

**Energy Efficiency Programs & Miscellaneous Comments**
"Just a few more questions"

Q30. Are you aware of utility/non-profit energy efficiency programs?

Q31. Our records show that __[company name]_ submitted about _X_ rebates through the program for high efficiency equipment installations. About what % of your high efficiency equipment sales does that represent? __%

Q32. With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)

Q33. Are there any other comments you would like to provide us to better understand the cost of residential air-source heat pumps?

That completes the questions I have. May I call you back at this number if I need to further clarify any of your responses?

Thanks again for your assistance with this important research.

NAVIGANT

NEEP EM&V Forum
Incremental Cost Study
Air Sealing Installer Interview Protocol

Company _____ Contact Phone_____

Survey Date_____ Measures _____

Hello. I'm calling on behalf of Northeast Energy Efficiency Partnerships (NEEP), a non-profit organization that fosters energy efficiency. Our member organizations are state governments, electric and gas utilities and non-profit energy efficiency program administrators such as (NYSERDA, or a local utility) that provide incentives to residential and business utility customers to make their homes and businesses more energy efficient.

This survey is being undertaken by Navigant Consulting of Burlington MA on NEEP's behalf. Its purpose is to determine the installed costs of residential air sealing. By understanding the incremental cost of measures, NEEP and its member organizations are able to more effectively evaluate the program's impact on the market.

**To show our appreciation for you taking the survey, you will receive a copy of the final results which will include the average prices that firms like yours are charging for various high efficiency products.**

Would you be willing to take the survey now, or could we schedule a time when it's convenient for you?

Your survey responses will be combined with those of similar firms to guide program planning and evaluation efforts. **All information you provide will be confidential and not linked to your company in anyway. No one outside of the project team will have access to your individual, non-aggregated responses.**

[*If respondent is ready to proceed with the survey*] The following questions ask about your company's work in air sealing of single family homes. Please answer the questions as completely as you can. If you do not know the answer to a particular question, please provide your best estimate.

[*IF PERSON EXPRESSES CONCERN ABOUT WHO WE ARE, WHAT SURVEY'S ABOUT*] If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

Thanks for your assistance with this important research.

What is your name?

What is your job title?

Please briefly describe your main work responsibilities

What's your general sales area? (may be region(s) of a state, multiple states – probe where, etc.)

Who are your primary customers – builders, homeowners? (Get details if multiple )

Air Sealing projects completed **in the past year.**
About how many air sealing projects do you complete each year?

How many of those are in new homes in a typical year?

How many are in existing homes?

Do you conduct a blower door test before and after each air sealing project to measure results?

**Cost Tables**

What is the typical cost per square foot for air leakage reduction? What is your cost per CFM reduced? **(IF INSTALLER DOESN'T PRICE EITHER WAY)** How do you price air sealing?

| New Construction | | | Retrofit | | |
|---|---|---|---|---|---|
| **CFM Reduction** | **Cost ($/sf)** | **Man hours (per sf, 1000sf, or CFM?)** | **CFM Reduction** | **Cost ($/sf)** | **Man hours (per sf or 1000sf)** |
| 1.0 | | | | | |

Do these costs include a markup? If so, what is the markup?

For our purposes, we estimate a contractor charges a customer about $60/hour for air sealing services. Does this sound about right?

k. Y / N:
   i. If No, is it High / Low:
   ii. By about how much ____$/hr or _____%

[*This question may be sensitive but we will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

How is the labor required for air sealing in the new construction market different from existing homes?

Can you give me a list of the typical air sealing measures you use to achieve leakage reduction?

What portion of your air sealing projects require you to install additional ventilation?

- What type of ventilation do you typically install in these cases? (fan type/location, size, etc)

- What is the average cost of equipment required for additional ventilation?

- How long does it usually take to install additional ventilation, when necessary?

Do you commonly conduct any combustion appliance zone (CAZ) testing or spillage testing before air sealing or after air sealing work has been completed? (If so, ask for details).

How long does this usually take?
How is the combustion testing priced?

**Efficiency Programs**

Are you aware of utility energy efficiency programs? (different phrasing for VT, NY, MD

Does your company participate in them?

With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)

About how many projects do you complete per year that are eligible for an efficiency program rebate (not tax credits)

About how many projects do you complete per year that receive an energy efficiency program rebate?

Are there any other comments you would like to provide us to better understand the cost of residential air sealing?

NAVIGANT

**NEEP Insulation Installer Interview Protocol**

| | |
|---|---|
| **Company:** | |
| **Location:** | |
| **Phone:** | |
| **Date:** | |
| **# of Rebates Issued** | |
| **Status:** | |

Hi, my name is ___, with Navigant Consulting. I'm working on a study of residential insulation for NEEP. I was hoping to speak with someone in sales about the installations you all completed over the last year?

If you have questions about the survey, please contact Elizabeth Titus at Northeast Energy Efficiency Partnerships, 781-860-9177, Extension 111.

**What is your name?**

**What is your job title?**

**Please briefly describe your main work responsibilities.**

**Who are your primary customers – builders, other installers, homeowners?**

**Roughly how many installations did you do last year?**

**Could you estimate what portion of your installations are:**

| | **Residential** |
|---|---|
| **Retrofit** | |
| **New Construction** | |

NAVIGANT

## INSTALLATIONS OVER THE PAST YEAR

**About what portion of your installations in the past year were the following types?**

(What type of insulation do you mostly install? Do you ever install other types?)

| Insulation Type | Total Number of Installations | % of Total Installations |
|---|---|---|
| Fiberglass batts | | |
| Dense Pack Cellulose | | |
| Loose Fill Cellulose | | |
| Spray Foam | | |
| Rigid Foam | | |
| Isocyanurate | | |
| Other (combination) | | |

**For what reason do you primarily install [insert primary insulation type]?**

**About what percentage of your installations in the last year were in the following location and what is the average size in square feet for each?**

| Installation Location | Percentage All Sales | Average Size for Retrofit(sf) | Average Size for NC (sf) | Type of Insulation |
|---|---|---|---|---|
| Attic | | | | |
| Wall | | | | |
| Basement | | | | |

**Do you have any specific insulation types or offerings to exceed building code?**

what type is used to exceed code.

**COST OF INSULATION**

**What is the typical cost per square foot of installing insulation in the following locations: (Ask about types of insulation used to reach desired R-value)**

| | New Construction | | | | | | Retrofit | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Location | R-Value | Type | Material Cost ($/sf) | Labor Cost ($/sf) | Installation Man hours (avg size) | | R-Value | Type | Cost ($/sf) | Installation Man hours (avg size) |
| Baseline Attic | | | | | | | | | | |
| Upgrade Attic | | | | | | | | | | |

| | New Construction | | | | | | Retrofit | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Location | R-Value | Type | Cost ($/sf) | Labor Cost ($/sf) | Installation Man hours (avg size) | | R-Value | Type | Cost ($/sf) | Installation Man hours (avg size) |
| Baseline Sloped Ceiling | | | | | | | | | | |
| Upgrade Sloped Ceiling | | | | | | | | | | |

| Location | New Construction | | | | | | Retrofit | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-Value | Type | Cost ($/sf) | Labor Cost ($/sf) | Installation Man hours (avg size) | | R-Value | Type | Cost ($/sf) | Installation Man hours (avg size) |
| Baseline Wall | | | | | | | | | | |
| Upgrade Wall | | | | | | | | | | |

| Location | New Construction | | | | | | Retrofit | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-Value | Type | Cost ($/sf) | Labor Cost ($/sf) | Installation Man hours (avg size) | | R-Value | Type | Cost ($/sf) | Installation Man hours (avg size) |
| Baseline Basement | | | | | | | | | | |
| Upgrade Basement | | | | | | | | | | |

| Location | New Construction | | |
|---|---|---|---|
| | R-Value | Cost ($) | Installation Man hours (avg size) |
| Baseline Slab | | | |
| Upgrade Slab | | | |

**Do these costs include a markup? If so, what is the markup?**

**Are there other material costs, aside from the insulation, that aren't included here? (attic ventilation, minor repairs, etc)?**

**For our purposes, we estimate a contractor charges a customer about $60/hour for installation services. Does this sound about right?**

. Y / N:

i. If No, is it High / Low:

ii. By about how much ? $/hr or %

[*We will keep your answer confidential and use it only to estimate average labor costs for installed equipment*]

**EFFICIENCY PROGRAMS**

**Are you aware of utility/non-profit energy efficiency programs?**

**With what utilities/energy efficiency organizations' programs do you participate? (could be multiples)**

**About how many installations do you complete per year that are eligible for an efficiency program rebate? (ask RET vs NC)**

**How many of those typically receive a rebate?**

**What is the name of your current distributor(s)?**

**Could you provide a contact name(s) and number(s)?**