INCREMENTAL COST STUDY PHASE TWO FINAL REPORT

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

Navigant Consulting, Inc.
77 South Bedford Street
Suite 400
Burlington, MA 01803

781.270.8366
www.navigant.com

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Glossary of Terms

ACH = Air Changes per Hour
AFUE = Annual Fuel Utilization Efficiency
ASHP = Air-Source Heat Pump
BCF =Base Cost Factor: Normalization used for data analysis and reporting specific market costs
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
EM&V = 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 Advisory Group
TRC = Total Resource Cost
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 www.neep.org/EM&V-forum.

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Technical Advisory Group
David Bebrin, Northeast Utilities
Whitney Brougher, National Grid
Chris Coll, New York State Energy Research and Development Authority (NYSERDA)
Debi Drake, Baltimore Gas and Electric (BGE)
Drew Durkee, ICF on behalf of BGE & PEPCO
Scott Harrington, Vermont Gas
Dave Jacobson, NEEP
Nikola Janjic, Vermont Energy Investment Corp.
Monica Kashru, NSTAR
Antonio Larson, Berkshire Gas
Brian McCowan, for NEEP
Chris Neme, for NEEP
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Executive Summary

This report presents the results of the Second Phase 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. ICS Phase Two follows the Phase One 2010-2011 Incremental Cost Study, and includes further investigation of certain measures from the ICS Phase One study, where further verification and examination was believed to be warranted. This additional scrutiny of ICS measures, including an investigation into premium pricing of energy-efficient consumer appliances, was designated as Task 1. The ICS Phase Two report also includes initial cost research on 12 additional measures, including final costs on 8 measures designated as Task 2. Base Cost Factors (BCFs)[1] for each study measure are presented in the report body and a complete set of cost tables is sorted by market in Appendix A. The workbooks supporting the costs developed for these measures can be found on the Regional EM&V Forum website at http://neep.org/forumThe report describes the methods and results of the ICS Phase Two study, and addresses a number of cost and research issues that impacted the study along the way.

The EM&V Forum and the Research Subcommittee

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 (RFP) 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 the determination of financial incentive levels."

Incremental cost studies have typically been technically 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.

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[1] Base Cost 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. These cost factors are developed by RS Means and updated annually. In Phase Two, Navigant applied the updated factors to any data collected in Phase One used in the Phase Two analysis.

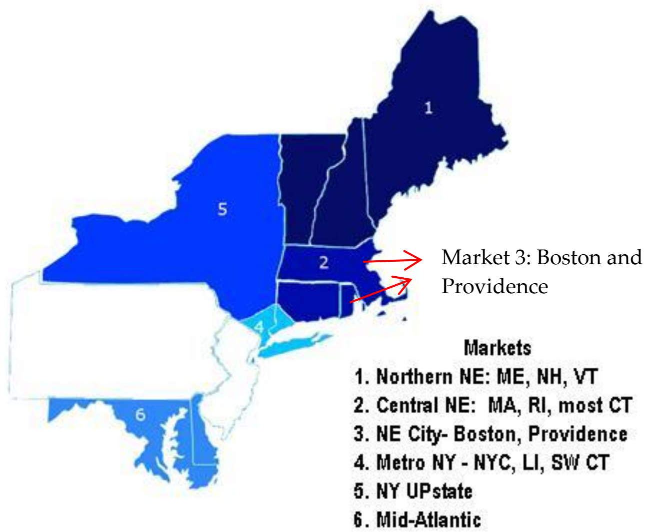
Updates of existing studies often pointed to far older studies as their primary sources. However, newer energy efficiency markets such as the Forward Capacity Markets initiated by Independent System Operator-New England and PJM adopted rigorous EM&V guidelines that could call many updates into question because of the cost data vintage. Further, increased national baseline efficiency standards for several popular energy efficiency measures added new pressures on cost-effective program design. Finally, 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 cost 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 Phase One and ICS Phase Two studies 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 and District of Columbia involved in the ICS covered six markets identified by the project team, using data from R.S. Means. They include New England, New York, and the Mid-Atlantic states of Maryland, Delaware, and the District of Columbia. Figure 1 shows the six markets identified.

To go to the full tables for each measure by market, click on the Market Number hyperlink in Figure 1 below.

Figure 1. ICS Markets



Source: R.S. Means

Market	Market Code	Market Territory	Base Cost Factor[2]
Northern New England	1	ME, VT, NH	0.85
Central/Southern New England	2	MA , RI, most CT	1.06
New England City	3	Boston, Providence	1.13
Metro New York	4	NYC, metro suburbs Southwest CT	1.29
Upstate New York	5	Albany, Buffalo, Rochester, balance of the state	1.00
Mid-Atlantic	6	MD, DE, DC	0.95
Base Cost Factor (BCF)*	-	-	1.00

*BCF is used to normalize data collected from different markets for analysis on a single platform.

[2] Base Cost 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. These cost factors are developed by RS Means and updated annually. In Phase Two, Navigant applied the updated factors to any data collected in Phase One used in the Phase Two analysis.

Use of the Incremental Cost Study

The ICS research team took great pains to carefully establish the costs presented in the ICS and to respond to concerns raised by reviewers. 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 efficiency. 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. To aid study users, we have estimated and indicated the likely persistence of the costs determined in this study for factors besides normal inflation adjustments.

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.

Finally, how efficient equipment is specified may vary among jurisdictions or change over time within jurisdictions as a whole or by individual program administrators. 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.

In addition to the tables contained in this report, the complete workbooks for each measure will be provided directly to the Subcommittee, and will also be made available on the EM&V Forum website.

Summary of Measures Studied in the ICS Phase Two Study

The ICS Phase Two considered a total of 14 measures; 6 measures involved follow-on work from Phase One, and 8 measures were new for ICS Phase Two. Six of the eight new measures were Commercial and Industrial (C&I) and six measures were electric. Table 1 below, briefly summarizes all measures and their status.

Table 1. Summary of ICS Phase Two Measures

Measure	Sector	Fuel	Application	Cost Type	Costs Provided
Task 1: Additional Work on Phase One Measures					
Combination Heat Hot Water	Res	Gas	ROB	Inc	X
Condensing On Demand Water Heaters	Res	Gas	ROB	Inc	X
Insulation, Attic, Cellulose	Res	Gas	RET	Inc	X
Residential Central Air Conditioning	Res	Electric	ROB	Inc	*
Air Sealing	Res	Gas	RET	Full	NP
Gas Boilers	C&I	Gas	ROB	Inc	NP
* Examined premium pricing issues only					
Task 2: New Measures					
Prescriptive Chillers	C&I	Electric	ROB	Inc	X
Dual Enthalpy Economizers	C&I	Electric	RET/NC	Inc, Full	X
Variable Frequency Drives	C&I	Electric	RET	Inc	X
Residential Ductless Mini-Splits	Res	Electric	RET/NC	Inc, Full	X
ENERGY STAR Ventilation Fans	Res	Electric	ROB/NC	Inc, Full	X
Commercial Refrigeration Compressors	C&I	Electric	RET, ROB	Inc	NP
Boiler Controls	C&I	Gas	RET/NC	Full	NP
Energy Management Systems	C&I	Gas/ Electric			NP

KEY: RET = Retrofit, ROB = Replace on Burnout, NC = New Construction, NP = Not Pursued, Inc = Incremental

ICS Research Methodology and Process

Navigant Consulting, Inc. (Navigant), collected and analyzed data for ICS Phase Two in the same way and using the same process as it did for the Phase One study. The full methodology is detailed in Section 4 of this report. Briefly, Navigant used the following process for all ICS Phase Two measure research:

1. For Task 1 follow-on measures, Navigant reviewed measure characterization from Phase One research and updated if needed.
2. For Task 2 new measures, Navigant created new characterizations and reviewed them with the relevant TAG.
3. Employed a standard protocol for collecting materials and labor costs, built on the Phase One protocols, with adjustments for particular measure characteristics or costing as needed.
4. Obtained data from program administrator databases to the extent possible for each measure, describing characteristics of measures installed and installer contact information, but not costs.
5. Developed interview quotas based on achieving 90/10 precision[3] and available time required per completed interview (based on ICS Phase One experience) and budget resources. Quotas assumed equal interview distribution from the six markets for each measure. Researchers attempted to interview installers from each market, which was generally not possible. Not all program administrators offered the project measures, and for most measures Navigant received program data from only a limited number of program administrators. Conducted phone interviews of installers for each measure, using a combination of program administrator contact information (some of that from websites) and where needed, cold calling. Navigant completed 104 interviews. In order to achieve that number, Navigant staff made 1,015 calls.
6. Obtained some limited additional data from program administrator invoices, Internet costs, and prior studies.
7. Placed all data for each measure on a single analysis factor using updated RS Means[4] factors to create Base Cost Factor results for each measure.
8. Using RS Means updated factors and updated inflation costs, generated preliminary materials and labor costs for each measure for each market. Preliminary costs were closely reviewed by the TAGs and adjusted in response to TAG comments and issues. Technical Advisors included program administrator staff, implementation contractors, and NEEP consultants, who effectively critiqued the costs and helped Navigant present costs in a manner most useful to program administrators, planners, and evaluators. The Phase Two review process (measure characterization and preliminary cost reviews) was both broader and deeper than the Phase One review process experience. NEEP, Subcommittee members, Technical Advisors, and Navigant invested increased time and effort, leading to very robust Phase Two results.

Note: Only BCF costs are shown in the executive summary and the report body. Costs for all markets are shown by market and measure in Appendix A.

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[3] 90/10 precision means at the 90% confidence interval, results will be within ±10% of the analyzed costs.

[4] RS Means is a supplier of construction cost information targeted to new building construction and renovation projects. Navigant used RS Means cost factors to develop cost factors for each of the six markets in the ICS Phase One and Phase Two studies.

Incremental Cost "Shelf Life"

Navigant and others have noted that incremental cost studies are often difficult to implement and expensive to underwrite. The EM&V Forum's sponsored research is one way to mitigate the expense by pooling resources across a number of program sponsors throughout the Northeast and Mid-Atlantic states.

A further question is once these costs are determined, what can we expect about their shelf life? How long can these costs be considered reliable before further investigation is required? There are several factors that can affect shelf life, such as the following:

- Technology changes
- Changes in the market appeal and purchase of appliances and equipment
- Changes in manufacturing that reduce costs (i.e., scaling up from increased demand, automation, and use of less expensive materials)

One example of expected change was found in On Demand water heaters. In the ICS Phase One, the presence of condensing units in the marketplace was believed to be quite limited. A year later, condensing units have essentially become the marketplace for this efficient technology. Residential Mini-Splits are another measure in which technology and market acceptance in the Northeast have changed greatly; single-room units were the most common configuration in the very recent past but multi-room units are becoming much more common and should be studied further. Other measures researched in this study are not expected to undergo dramatic changes. To assist NEEP and the project sponsors, Navigant has estimated the likely stability of the costs reported in this study. We have done this by consulting with informed individuals within the industries and within Navigant's own energy group. Table 2 shows expected shelf life for all study measures, included in Task 1 and Task 2.

Table 2. Measure Cost Shelf Life

Measure	Expected Cost Life	Comments
Task 1 Measures		
Combination Heat/Hot Water Units	Frequent	Expect increased penetration. Combination units are becoming an increasingly cost-effective option compared to conventional boiler/water heater systems for many homeowners.
Condensing On Demand Water Heaters	Medium	Surveyed products already meet 2015 standard.
Attic Insulation-Cellulose	Stable	No major changes expected in the next 3-5 years.
Residential Central Air Conditioning	Medium	Standards change may bring down manufacturing costs through increased scale.
Task 2 Measures		
Prescriptive Chillers	Medium	
Dual Enthalpy Economizers	Medium	
Variable Frequency Drives (VFDs)	Medium	
Residential Ductless Mini-Splits	Frequent	Expect increased penetration of heating/cooling units in cold climates and multi-room units.
ENERGY STAR Ventilation Fans	Medium	No updated ENERGY STAR specs currently in development. The most recent ENERGY STAR spec, version 3.2, was updated April 2012.
Commercial Refrigeration Compressors	Started but not pursued[5]	
Commercial Boiler Controls	Not Studied	
Energy Management Systems	Not Studied	
Key		

[5] The sponsoring program administrator most active on this measure determined in summer 2012 that its own measure characterization required review and update, putting the cost study for the measure on hold. Later, the PA recommended not pursuing cost work because the measure needed re-thinking and re-packaging.

Measure	Expected Cost Life	Comments
Stable - No expected Technology or Standards changes Update for annual inflation only next 3-5 years		
Medium - Codes/Standards changes possible 1-3 years		
Frequent - Market/Technology changes will affect measure characterization/costs in 1-3 years.		

Task 1 - Follow-On Research

Following completion of the 2010-2011 ICS, the Subcommittee desired additional research on several measures, for a variety of reasons, primarily to refine certain ICS findings. Navigant presents the follow-on research requested by the Subcommittee, referred to as Task 1, including the following:

» Condensing On Demand water heaters[6]
» Combination heat and hot water units
» Cellulose-insulated attics
» Commercial boilers
» Residential air sealing
» An investigation on premium pricing centered on residential air conditioning (AC)

Navigant also considered performing additional research on Commercial boilers and Residential air sealing in existing homes but determined, with Subcommittee agreement, that further work on these measures was not needed. Table 3 summarizes the Task 1 measures, including reasons for eliminating measures from the Task.

[6] This measure was initially included in Task 2. Navigant collected substantial data on condensing units in the ICS Phase One while researching non-condensing units, which appeared to be the dominant form of the measure when Phase One was scoped, but the market changed dramatically during the study. Navigant was able to use this data as a starting point for developing the incremental cost work. Therefore, the study team did not regard the measure as "new" and moved it into the Task 1 group, with NEEP and Subcommittee approval.

Table 3. Task 1 Measure Issues

Measure	Issue	Results
Combination Heat/Hot Water	» Understand bifurcated market, pricing concerns on a new measure » Base Case – is replace on boiler burnout most appropriate? Should cost of hot water heater replacement be included?	» 'Bifurcated market' actually included units found to be non-compliant with ENERGY STAR. Removed those units and bolstered original data set with additional interviews for compliant equipment. » Result: Cost increases of 28% » Base case remained the same for the ICS but other scenarios could be developed.
Condensing On Demand Water Heaters (moved from Task 2 to Task 1)	» ICS Phase One reported non-condensing units. ICS Phase Two researched condensing units	» Supplemented 2011 cost data with additional interviews
Attic Insulation using Cellulose	» Attic Insulation Disaggregated by material type » Refine labor costs	» Completed interviews on cellulose open blow attics – Costs established per sq. ft. all-in. » Result: Costs for cellulose only decreased 51% from 2010 rolled-up costs. » Costs not applicable to MA insulation pricing*

Residential Central Air Conditioning	» "Premium Pricing", AC, and other appliances » "Big Box" participation	» Res AC - could identify *perhaps* 2-2.5% "non-energy" manufacturing costs but bounds of energy/non-energy costs not clear. Expect this problem to impact similar analysis for other appliances and equipment. » Big box interview attempts not fruitful – interviewed nine installers on customer priorities and dealer influence on customer purchase decisions. » Result – Discussion on topic below and full memo attached as Appendix B
Air Sealing	» Validate protocols in existing buildings for baselines and results. Concern raised about compliance with ENERGY STAR protocols	» Determined that ICS protocols were appropriate for existing buildings. ENERGY STAR protocols apply only to new construction. » Result: No further research required.
Commercial Boilers	» Baseline question » Concern on decreasing cost increments, suggesting additional data required to bolster ICS findings » Concern the ICS reached the "right" respondents within the companies interviewed	» Baseline question resolved – really a full costs question. » Decreasing cost increments found to result from manufacturer small changes such as tweaking controls. » Result: No further research required.

*MA has an insulation fee schedule developed under a separate methodology.

Task 1 - Measure Costs

The tables in this section below were developed through the data collection summarized above and described in detail in sections 3 and 4 of this report. Only BCF[7] costs are shown in this summary and the report body. The full panoply of cost tables is shown by market for each measure in Appendix A. The costs shown for Tasks 1 and Task 2 are total costs, including materials and labor, to permit showing tables at a reasonable level of legibility.

Combination Heat and Hot Water

Research Rationale

The 2011 Combination unit analysis raised several questions that warranted a follow-on research effort in 2012. First, the 2011 data showed a bifurcated market representing two distinct price ranges; one range was on par with the residential boiler market and the other range included exclusively one manufacturer's units at significantly lower cost. We learned that the line of lower cost units did not conform to ENERGY STAR standards and dropped them from the analysis. Second, the 2011 analysis did not include raw data collected from the Mid-Atlantic region, so we targeted Maryland to make sure it was properly represented. Last, this year we inquired directly about typical baseline scenarios when speaking with contractors to better understand when homeowners decide to install combination units.

Research Results

Table 4 shows the incremental costs of the various capacities and efficiencies. Eliminating the lower cost units and adding new data on qualifying units, costs increased approximately 45% on average from Phase One.

Table 4. Combination Heat and Hot Water Incremental Costs

2012 Results - Incremental				
Size (MBH)	BCF - Installed Cost ($/Unit)			
	90% CAE	91%CAE	93% CAE	95% CAE
110	$1,780	$2,059	$2,619	$3,179
120	$1,836	$2,115	$2,675	$3,234
126	$1,869	$2,149	$2,709	$3,268
150	$2,004	$2,283	$2,843	$3,402
199	$2,278	$2,558	$3,117	$3,677

Baseline assumes Replace on Burnout of a standard hot water residential boiler rated at the Federal Minimum Annual Fuel Utilization Efficiency (80 AFUE).

Condensing On Demand Hot Water Heaters

[7] The updated BCS cost factor currently equals Market 5 factors; in future updates of RS Means market factors this equivalence may not continue.

Research Rationale

On Demand water heaters were a measure in the first ICS. In mid-2010, when the measure list was developed, the Subcommittee believed that condensing units were not a large part of the market for this measure and the research focused on non-condensing units. At that time, however, data was also collected and reported on higher efficiency condensing units. In ICS Phase Two, the Subcommittee requested further exploration focused on condensing units, categorizing this measure as a "new", Task 2 measure. However, Navigant reviewed its characterization and collected data from the first project and recommended that supplemental data collection and analysis would be sufficient to provide up-to-date costs. Navigant applied R.S. Means and inflation adjustments to the older data and collected additional data from program administrators in several states.

Table 5 shows the incremental costs against standard efficiency water heaters at 180 and 199 MBH capacity levels, equivalent of 30-, 40-, and 50-gallon conventional water heaters, assuming a standard installation. Table 6 assumes a more complicated installation that may occur in older or unusually configured homes.

Table 5. Condensing On Demand Water Heater Incremental Costs for Stand Installations

	Base Cost Factor Incremental Cost ($/Unit)			
Size (MBH)	Full Cost Standard On Demand Water Heater (82 EF)	Condensing On-Demand Water Heater (94 EF)	Condensing On-Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,729	$2,506	$2,557	$2,608
180	$1,637	$2,415	$2,466	$2,516
180	$1,564	$2,342	$2,392	$2,443
199	$1,665	$2,443	$2,493	$2,544
199	$1,528	$2,305	$2,356	$2,407

Table 6. Condensing On Demand Water Heater with Additional Installation Costs for Non-Standard Installations

Size (MBH)	Base Cost Factor Incremental Cost ($/Unit)			
	Full Cost Standard On Demand Water Heater (82 EF)	Condensing On-Demand Water Heater (94 EF)	Condensing On-Demand Water Heater (95 EF)	Condensing On-Demand Water Heater (96 EF)
180	$2,116	$2,894	$2,944	$2,995
180	$2,024	$2,802	$2,853	$2,903
180	$1,951	$2,729	$2,779	$2,830
199	$2,052	$2,830	$2,881	$2,931
199	$1,915	$2,693	$2,743	$2,794

Attic Insulation Using Cellulose

This measure presents the full cost per square foot on open attics insulated with cellulose, as shown in Table 7. The ICS Phase One considered a number of insulation measures but rolled up the costs of separate insulation materials and did not isolate the costs for cellulose. Navigant also had some concern about the labor costs reported with respect to "open blow" attics with cellulose insulation. Asking for labor costs for a variety of applications and materials may have unintentionally increased the labor cost for this straightforward application. In Phase 2, Navigant performed additional data collection for a typical "open blow" attic (no or few obstructions), re-examined labor costs, and presented the results on a $/sq. ft. insulated cost basis. The costs presented below assume no or negligible existing attic insulation.

Table 7. Attic Insulation Using Cellulose

Blown Cellulose Attic Insulation	Base Cost Factor - Installed Cost ($/SF)		
	R38	**R49**	**R60**
Material Costs	$1.15	$1.24	$1.32
Labor Costs	$0.77	$0.77	$0.77
Total Installed Cost	**$1.92**	**$2.01**	**$2.10**

The incremental cost numbers for this measure are relevant to each of the states supporting the study with the exception of Massachusetts. Massachusetts has a unique situation in this market. In all the states studied, except Massachusetts, insulation contractors are responsible for recruiting participants for insulation work. Massachusetts program administrators recruit residential participants through their jointly operated Mass Save gateway, and assign participating insulation contractors to do work under a standard fee schedule developed by program operators using a separate methodology.

Premium Pricing in Residential Air Conditioning and Other Consumer Appliances

Navigant has researched the extent and cost impacts of premium non-energy-saving features in residential central AC units to determine if these added feature costs could be pulled out of the measure cost for this exercise. The issue of concern here is that cost-effectiveness is being affected by the inclusion of costs that do not contribute to energy efficiency but are taken into account in Total Resource Cost (TRC) test. Navigant also considered whether this phenomenon might lead to a premium pricing metric or for residential AC. A robust metric would potentially apply to other consumer appliances where premium features increase price without increasing the unit's energy efficiency. This work resulted from interests of the Regional EM&V Forum Research Subcommittee that arose in the course of the ICS Phase One, conducted by Navigant. In the Phase Two study, the Subcommittee directed Navigant to investigate the following questions:

1. Are energy-efficient central AC systems packaged with additional features that add to the unit cost and incremental cost between standard and efficient units?
2. Can the costs of identified features be quantified, enabling program administrators to obtain a clearer understanding of the costs of increasing energy efficiency from SEER 14.5 to SEER 15 and above?
3. What can we say about premium pricing that may affect the costs of other types of energy-efficient consumer appliances? Can we establish a premium cost metric or methodology that would lead to reliably quantifying premium costs?

Given the increasing cooling load in the Northeast resulting from first-time installation of residential central AC, as well as increased purchases of room AC units, the penetration of highly energy-efficient central AC becomes increasingly important. A 2003 study on the impacts of climate change and electricity consumption noted that:

> *Although the temperature-induced increases in market penetration of air conditioning had little or no effect on residential energy consumption in cities such as Houston (93.6% market saturation), in cooler cities such as Buffalo (25.1% market saturation) and San Francisco (20.9% market saturation), the extra market penetration of air conditioning induced by a 20 percent increase in CDD[8] more than doubled the energy use due to temperature alone.[9]*

Central AC systems are long-lived measures. Program planning typically assumes measures lives of around 15 years[10] but units can function well in excess of 20 years. Customers making first-time purchases in existing homes that previously were not centrally cooled are making a considerable investment. Such customers can be expected to be very sensitive to first cost. But they may also consider convenience and various premium features for a system they expect to live with for many years. Dealers have an opportunity to increase their profits by emphasizing the relatively small additional cost of mid-line and top-line units, if customers consider those costs over 15 years. Thus, dealer recommendations and customer preferences can affect residential cooling energy use over an extended period. However, it's not clear from this brief study what customers are actually buying. The dealers we spoke with overwhelmingly found customers to be focused on cost first, and mentioned few features that would fall into the premium set, mainly noise reduction. The full premium pricing research memo is found in Appendix B.

Approach to the Premium Pricing Issue

This paper presents the results of Navigant's investigation and analysis of residential AC premium features. Navigant's approach to assessing the three questions presented included a close look at manufacturer marketing efforts to identify the premium features. This report also explores the extent to which AC systems are packaged with additional features.

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[8] CDD = Cooling Degree Days. Based on the day's average temperature minus 65°F, relating to the demand for air conditioning. Source: National Weather Service.

[9] David J. Sailor and A. A. Pavlova. 2003. "Air Conditioning Market Saturation and Long-Term Response of Residential Cooling Energy Demand to Climate Change." *Energy* 28: 941-951.

[10] Michigan MEMD Database for deemed measure savings.

Following the analysis of premium features and how they are bundled, Navigant conducted brief interviews with nine Massachusetts installers to assess customer demand for these premium features.

Premium Features

Through investigation of manufacturer marketing materials, Navigant identified four premium features:

- Durability and Appearance
- Comfort and Noise Reduction
- Improved Warranty
- Improved Controls, Sensors, and Alarms

Question 1. Are energy-efficient central AC systems packaged with additional features that add to the unit cost and incremental cost between standard and efficient units?

Answer 1. Yes, they are.

The study found that Residential central AC systems are packaged with a variety of non-energy features that vary from manufacturer to manufacturer. Non-energy features include aspects such as:

- Durability and Appearance
- Comfort and Noise Reduction
- Improved Warranty
- Improved Controls, Sensors, and Alarms

Manufacturers typically offer a base tier, a mid-tier, and a top tier. Some premium features are introduced in the mid-tier units and further enhanced in the top tier, where additional features are also added. Manufacturers often reserve premium features for higher efficiency units to differentiate their product offerings. Some features are not offered across a manufacturer's entire product range within a given efficiency rating. This makes isolating features as *premium* features more difficult.

Question 2. Can the costs of identified features be quantified, enabling program administrators to obtain a clearer understanding of the costs of increasing energy efficiency from SEER 14.5 to SEER 15 and above?

Answer 2. No, not with certainty at this time.
While Navigant took a few different approaches to identifying costs associated with additional features, they could not be quantified with any level of confidence. Because of manufacturer bundling of premium features in higher efficiency AC units, dealers/contractors were unable to break out costs of specific premium features. Navigant's own earlier work for the U.S. Department of Energy (DOE) focused on determining the costs of increasing efficiency standards and the manufacturing economies of scale that occur as the baseline is moved upward, and was not oriented toward the premium features. A review of "non-energy" features, conducted long after the tear-down analysis[11] was completed, identified as much as 2.5 percent of manufacturing costs as "non-energy", including features "like sound blankets that are typically not found on entry-level units and whose purpose is 100 percent not related to energy efficiency."[12] The project team leader went on to say:

> "In short, there isn't much that a manufacturer throws at a central AC unit that isn't somehow efficiency related. Efficiency, size, and noise remain the main pillars of differentiation, as best as I can tell in a market where ***anything below 16 SEER has been pretty well commoditized (emphasis added)***, thanks to standards, rebates, and other incentives. For example, Carrier won't offer Infinity controls for systems that cannot (theoretically) reach 17 SEER."[13]

The comment about SEER 16 is significant. Currently, program administrators offer incentives on residential AC that exceed 14.5 SEER. In a "thoroughly commoditized" market, manufacturers have made all the economies they can achieve and customers are seeking price and perhaps brand as the purchasing determinants. The question of the role of premium features, therefore, comes into play mainly at levels above the current standards.

The mix of features among the three tiers varies among the manufacturers therefore, it is not possible to say a mid-tier unit always includes a particular non-energy feature, no matter who manufactures the unit.

Question 3. What can we say about premium pricing that may affect the costs of other types of energy-efficient consumer appliances? Can we establish a premium cost metric or methodology that would lead to reliably quantifying premium costs?

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[11] A tear-down analysis is the disassembly of commercially available equipment, such as central air conditioning, to determine the unit's components and the manufacturing costs from the component level upward. This approach is used by DOE as part of regulatory analysis reviewing proposed efficiency standards.
[12] Constantin von Wentzel, Navigant Project Manager on DOE Appliance Regulation projects, personal communication, 8/17/2012.
[13] Constantin von Wentzel, personal communication, 8/17/2012.

Answer 3. With the current research under this limited scope of work, Navigant was not able to develop a premium cost metric or approach. Further research taking other approaches may prove more fruitful in establishing premium cost factors.
A small number of supplemental interviews conducted in this study provide an anecdotal window into customer priorities but a more substantial customer sampling would provide a clearer picture. Dealers report that customer decisions are driven by price but dealers are quick to point to efficiency program rebates, which they believe move customers up the efficiency curve, meeting the program goals of increasing efficiency. A customer-centered study could probe these decisions further but with a different orientation from typical free-ridership/spillover studies. Questions might include:

- Do first-time customers, of which there are increasing numbers in existing homes, approach the purchase of a central AC system in the same ways as customers replacing existing equipment?
- What are the priorities and preferences of each group?
- From the customer perspective, what makes the sale in a general way and what further makes the sale for the more efficient units and the most efficient units?
- Do contractor reports about the impact of incentives on customer efficiency choices hold up?

Broader Applicability of the Premium Pricing Question

We have seen examples of other consumer appliances, refrigerators, and clothes washers as two examples, in which higher and highest efficiency units are packaged with a variety of premium features. The research team considered how additional research on central AC and other appliances might help develop a metric for the premium feature cost. With regulator agreement, such a premium index could be used to discount the full cost of efficient appliances for the purpose of determining cost-effectiveness.

However, further investigations in this area may find that pricing of premium features for other appliances is similarly opaque and difficult to reliably quantify. Manufacturers are understandably loath to provide cost data. They operate in a highly competitive environment and have concerns about confidentiality. Manufacturer associations such as the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) resist efforts to provide any shipment or sales data to efficiency researchers. Tear-down analyses are another potential research path that could shed light on the subject. These studies don't rely on manufacturer data and use robust materials, labor, markup and other cost estimators to develop costs. A premium feature tear-down analysis would require the researchers to develop protocols that would clearly delineate energy from non-energy features. Currently, there is no protocol focused on that issue.

Further investigation is beyond the scope of this ICS phase; however, we believe further explorations, including developing a comprehensive research framework, could prove useful toward answering the central question of the extent to which non-efficiency features affect the cost and cost-effectiveness of efficient consumer appliances.

Task 2 - New Measures for Phase Two 2012 Research

For Phase Two in 2012, the Subcommittee developed a list of additional measures, more heavily focused on the Commercial/Industrial measures than the initial ICS. Table 8 shows the Task 2 Measures.

Table 8. Task Two Measures

Measure	Sector	Fuel	Application	Cost Type	Costs Provided
Task 2: New Measures					
Prescriptive Chillers	C&I	Electric	ROB	Inc	X
Dual Enthalpy Economizers	C&I	Electric	RET/NC	Inc, Full	X
Variable Frequency Drives	C&I	Electric	RET	Inc	X
Residential Ductless Mini-Splits	Res	Electric	RET/NC	Inc, Full	X
ENERGY STAR Ventilation Fans	Res	Electric	ROB/NC	Inc, Full	X
Commercial Refrigeration Compressors	C&I	Electric	RET, ROB	Inc	NP
Boiler Controls	C&I	Gas	RET/NC	Full	NP
Energy Management Systems	C&I	Gas/ Electric			NP
KEY: RET = Retrofit, ROB = Replace on Burnout, NC = New Construction, NP = Not Pursued					

Of these measures, which are described in detail in section 3 of this report, Navigant recommended that the three measures should not be pursued, as shown in Table 9 below.

Table 9. Measures Not Studied

Measure	Reason for Not Proceeding
Commercial Refrigeration Compressors	Efficiency VT determined they set measure baseline too high – Navigant delayed research waiting for EVT. EVT has decided to set a baseline on a refrigeration package rather than the compressors alone. Few sponsors use measure in programs.
Commercial Boiler Controls	Navigant's characterization research revealed these controls now standard on new equipment and installers rarely recommend a retrofit. PA records show very few retrofits.
Energy Management Systems	This is really a custom measure. Navigant and Technical Advisors could not devise a usable prescriptive cost scenario that would be useful to a prescriptive program.

Prescriptive Chillers

Navigant characterized and established costs for three types of prescriptive chillers: air-cooled, water-cooled scroll (or screw), and water-cooled centrifugal chillers, shown in Table 10, Table 11 and Table 12, respectively. Details of the characterization are found in Section 3.2 of the report.

Table 10. Air-Cooled Chillers (BCF) Incremental Cost

Air-Cooled Chiller Incremental Cost/Ton Estimates (Categorized by Efficiency (EER)) Baseline EER = 9.60					
Capacity (Tons)	**9.60 EER**	**9.90 EER**	**10.20 EER**	**10.52 EER**	**10.70 EER**
50	$0	$229	$457	$701	$838
100	$0	$114	$229	$350	$419
150	$0	$76	$152	$234	$279
200	$0	$47	$93	$143	$171
400	$0	$23	$47	$71	$85

Table 11. Water-Cooled Scroll/Screw Chillers

Water-Cooled Scroll/Screw Chiller Incremental Cost/Ton Estimates (Categorized by Efficiency (kW/Ton)) Baseline Efficiency: 0.78 kW/Ton					
Capacity (Tons)	**0.78 kW/ton**	**0.72 kW/ton**	**0.68 kW/ton**	**0.64 kW/ton**	**0.60 kW/ton**
50	$0	$76	$126	n/a	n/a
100	$0	$38	$63	n/a	n/a
150	$0	$25	$42	n/a	n/a
200	n/a	$0	$61	$122	$183
400	n/a	$0	$31	$61	$92

Table 12. Water-Cooled Centrifugal Chillers

Water-Cooled Centrifugal Chiller Incremental Cost Estimates (Categorized by Efficiency (kW/Ton)) Baseline Efficiency: 0.64 kW / Ton				
Capacity (Tons)	**0.64 kW/ton**	**0.60 kW/ton**	**0.58 kW/ton**	**0.54 kW/ton**
100	$0	$73	$110	$183
150	$0	$49	$73	$122
200	$0	$37	$55	$92
300	$0	$61	$91	$152
600	$0	$30	$46	$76

Dual Enthalpy Economizers

Navigant projected costs for two scenarios: a full-cost scenario, assuming heating, ventilation, and air-conditioning (HVAC) equipment with no preexisting economizer, and an incremental cost scenario assuming an economizer with single enthalpy increased to dual enthalpy functions, shown in Table 13 and Table 14 below.

Table 13. Economizers Showing Full Cost

Base Cost Factor Total Costs			
HVAC System Capacity (Tons)	**Single Enthalpy Economizer**	**Dual Enthalpy Economizer Controls**	**Measure Total**
5	$773	$178	$951
15	$1,267	$251	$1,518
25	$1,761	$324	$2,085
40	$2,502	$434	$2,935
70	$3,984	$653	$4,636

Table 14. Incremental Cost of Single to Dual Enthalpy

Base Cost Factor Total Costs			
HVAC System Capacity (Tons)	Dual Enthalpy Control	Dual Enthalpy Control Installation	Measure Total
5	$106	$72	$178
15	$179	$72	$251
25	$252	$72	$324
40	$362	$72	$434
70	$581	$72	$653

Variable Frequency Drives (VFDs)

Navigant modeled VFDs at a variety of horsepower ratings to encompass the range of VFDs participating in energy efficiency programs. The most frequent sizes were found to be 15-25HP but VFDs were found in applications from 5 to 600HP. Table 15 presents the BCF costs for VFDs. Baseline is no VFD.

Table 15. VFD Costs

Size (HP)	Base Cost Factor ($/Unit)		
	Equipment Cost	Labor Cost	Total Installed Cost
5	$1,115	$1,135	$2,250
15	$2,183	$1,135	$3,318
25	$3,250	$1,135	$4,386
50	$5,438	$1,135	$6,573
75	$7,397	$1,135	$8,532
100	$8,848	n/a*	n/a
200	$15,301	n/a*	n/a

*Labor costs were not determined for these larger units.

Residential Ductless Mini-Splits

Navigant characterized and collected costs for a single-head (single-room) mini-split, based upon data found in program administrator databases. Costs for single-head units are found in Table 16. This analysis assumed full cost of the measure, assuming first-time measure installation. Comments received late in the review process suggested the following:

- Multi-head, multi-room units should be considered as well, since they are becoming increasingly popular. (2010 program administrator databases consulted for the market review did not show multi-head units receiving program incentives). However, this is a measure in which the market is rapidly changing and future research should look closely at multi-head units and the additional associated labor, which can vary greatly, depending upon the facility.

- Costs for low-efficiency mini-splits should be used as a baseline against higher SEERs to show the incremental costs of increasing efficiency. This was done and is shown in section 3.6.
- Costs of low-temperature mini-splits should be included. Some low-temperature units were found in the data set. These units may not be common enough in the marketplace yet to develop robust costs at this time, but should be considered in any future cost study.

Table 16. Residential Ductless Mini-Splits – Single Room

Total Installed Cost				
Size (Tons)	**Base Cost Factor Full Cost ($/Unit)**			
	13 SEER	**18 SEER (Lowest SEER with strong PA database representation)**	**21 SEER (Most represented)**	**26 SEER (Best available)**
3/4	$2,733	$3,078	$3,236	$3,460
1	$2,803	$3,138	$3,407	$3,363
1.5	$3,016	$3,374	$3,640	*
2	$3,273	$3,874	*	*

Labor costs were determined to be $1,736 per unit, regardless of size or capacity, for single-room units.

Residential ENERGY STAR Ventilation Fans

Navigant researched ENERGY STAR residential ventilation fans over a range of capacities, including fans with and without lights. Navigant has defined a baseline ventilation fan as a bathroom or utility ventilation fan that is not ENERGY STAR rated. Non-ENERGY STAR units are assumed to be the most economical to purchase. The efficient measure is defined as an ENERGY STAR-qualified ventilation fan for the same installation scenario.

While there are many features that ventilation fans may come equipped with, for the purposes of this study, Navigant collected data on standard units, which either come with an integrated light or without. Analysis was done to determine the added cost of an integrated light. Other features, such as the addition of a heating lamp, were not considered for this study and excluded from data collected

From the collected data, the following maximum CFM size ranges were used in the analysis of ventilation fan costs: 50–89 CFM, 90–149 CFM, and 150–310 CFM. Units outside these ranges were removed from the formatted data and were not used in the analysis due to insufficient data. There were only a few units below 50 CFM; they were not used in this analysis. Likewise, units above 310 CFM were also rarely encountered and not included in this analysis. Fan costs are shown in Table 17, Table 18, and Table 19 below.

Table 17. Residential ENERGY STAR Ventilation Fans Incremental

Material Incremental Cost			
Base Cost Factor ($/Unit)			
Feature	**CFM Range**		
	50-89 CFM	**90-149 CFM**	**150-310 CFM**
Exhaust only	$80.64	$68.66	$56.19
Fan with light	$123.34	$111.35	$98.89

Incremental costs assume a constant installation cost regardless of size or type.

Table 18. ENERGY STAR Ventilation Fans Replace on Burnout, Full Costs

Feature	CFM Range		
	50-89 CFM	**90-149 CFM**	**150-310 CFM**
Exhaust only	$324.75	$357.39	$386.80
Fan with light	$367.45	$400.09	$429.50

Table 19. ENERGY STAR Ventilation Fans New Construction Full Costs, Including Ducting

Feature	CFM Range		
	50-89 CFM	**90-149 CFM**	**150-310 CFM**
Exhaust only	$584.24	$616.88	$646.29
Fan with light	$626.93	$659.58	$688.99

Lessons Learned

During that time the research team examined more than 25 energy efficiency measures in both the residential and commercial/industrial sectors. This sort of research is highly labor-intensive. At its heart, the work requires identifying and defining measures, and interviewing and analyzing the responses of equipment installers across a wide range of measures and also a range of markets. Each stage of the project process poses a number barriers and Navigant believes good progress has been made in identifying the barriers and working toward the solutions, although it's clear that there is no smooth pathway for doing this work. Below we describe aspects of the study that have caused problems and our recommendations for improvements.

Measure Selection Criteria and Process

The EM&V Research Subcommittee has had the responsibility for selecting the individual measures to be studied, with assistance from NEEP. A few selected measures have turned out to be impractical to research, some for technical reasons, some for programmatic reasons, some because the market has evolved, as in the case of commercial refrigeration controls. Navigant suggests that for any further research, the committee adopt a scoring system that considers several important factors, including one or more of the following, not necessarily in order of importance:

- » Extent to which measure is offered by multiple participating project sponsors
- » Current or expected contributions to efficiency savings portfolios
- » Concentration on "widgets", discrete appliances or equipment, or whose boundaries are readily identifiable if connected to larger systems
- » Recently emerged maturing technologies (e.g., combination heat and water studied in the ICS Phase One and ICS Phase Two)
- » Climate-sensitive measures applicable to a specific region
- » Ready availability/accessibility of measure data in program administrator databases (identify who has best data in advance of selection)
- » Technical review by Program Administrator technical advisors as part of selection process

Early Identification of Data Resources

The basic methodology of the ICS studies has been costing of measures that are offered in energy efficiency programs, not a canvass of the entire market. For this reason, these studies have relied on the availability of program administrator data which describe the make/model of rebated equipment, and equally important, name and contact information for the measure installers. This approach allows researchers to develop characterizations that closely conform to the program-incented equipment. In the Phase One and Phase Two studies, Navigant canvassed participating program administrators once the study was in progress, which sometimes increased delays. Data at the level of detail needed are often held by implementation contractors and not program administrators, making the process of gaining access more time consuming. Early identification of data sources, in the measure selection process, would certainly help this situation. Navigant did look at some invoices for three commercial measures in the ICS Phase Two, thanks to the cooperation of National Grid. These invoices provided significant useful information for one measure and a minimal amount for the other two. Although the project measures were included in most of these invoices, costs were often not separated, nor were labor costs identified. Navigant concludes that the effort versus reward of collecting and examining the invoices does not point to this as a significant data source for future studies.

Increased Coordination with Technical Advisors and Program Implementers/Designers

Navigant had more success in Phase Two with soliciting and receiving comments on measure characterization and on preliminary costs in the ICS Phase Two, with some limitations. Each participating program administrator designated TAGs for each of the project measures. In addition, several program administrators and Navigant were successful in getting measure reviews from implementation contractors; program administrators also had some measures reviewed by their own consultants.

TAG responses to proposed measure characterizations were most helpful on technical issues. However, we sometimes learned, later in the study, that the technical issues discussed did not always match up well with current or potential programs offered by program administrators. Given the number of participating program administrators in the study, it isn't surprising that the baselines and efficient measure characterizations did not match every program; however, in some cases, getting a program-oriented review as well as a technical one could have avoided some time-consuming adjustments after data were collected and analyzed. Navigant recommends a tighter connection between technical and program reviews in any future cost work. We recognize that the time demands on program administrators often work against such tight coordination; however, the project as a whole is intended to aid the program administrators' planning and evaluation activities. We believe further effort should be invested at the characterization stage as well as cost review to get program-oriented feedback.

Finally, Navigant believes it is extremely important in a project of this complexity for NEEP as administrator of the project to have a dedicated Technical Advisor. The Technical Advisor should have a broad background in the specific measures being researched and/or related expertise in program design. Being able to call on this sort of expertise was extremely valuable for the Task 2 measures, particularly C&I measures. The need is not only for the technical skill but for the context of how program administrator energy efficiency programs are actually planned, implemented, and evaluated. Should the EM&V Forum decide to sponsor further rounds of cost research, we strongly recommend the inclusion of such an advisor as part of the team.

Recommendations for Future Cost Research

The ICS Phase Two expanded the scope of cost research, focusing more on commercial measures in this round of research. In thinking about future cost research, Navigant recommends that such work only focus on the following four areas:

1. Measures that are currently providing substantial contributions to energy efficiency portfolios
2. Measures in the current study that are estimated to experience frequent cost changes because of developing markets and/or technology changes. Combination Heat and Water Units and Residential Mini-Splits fall into this category.
3. Emerging technologies that are fully commercialized (and may now or in the very near future be offered in energy efficiency programs) but also still undergoing technical and market development and have the potential to make substantial contributions to savings portfolios
4. Further exploration of the premium pricing issue. In this particular case, Navigant recommends more consumer-focused research to gain a better understanding of what consumers value in the purchase decisions about energy-using equipment on the one hand. On the other hand, future primary research on the embedded costs of non-energy-saving premium features can also turn to a deep analysis of the sort provided by tear-down analyses that have been done for regulatory purposes. The tear-down work that has been done did not consider this issue and could only indicate where non-energy costs might be found and provide only very rough estimations of their cost contribution. A dedicated tear-down focused on premium features across multiple measures might shed significant light on the subject.

Additionally, Navigant suggests continuing work on two measures considered in this study. Residential Mini-Splits stand out as measures that have a growing role in residential programs and possibly in small commercial programs as well. Multi-head units are becoming more common, and with more installation experience, we would expect that establishing a range of labor costs will become more feasible. Technology changes figure into this measure as well. Low-temperature units are now available from two major manufacturers and we would expect that field to widen. Low-temperature units could play a substantial role in colder rural areas of the Northeast where fuel switching (primarily from oil heat) is permitted.

Navigant also believes that work on commercial refrigeration compressors should be considered. Though not currently a large savings contributor, this measure might have the potential for increased savings share going forward. Navigant suggests that Efficiency Vermont keep the Subcommittee current on how it approaches this measure moving forward.

Navigant invites readers of this draft report to recommend measures they think might be valuable for any future measure cost research as well. Getting recommendations early and screening following the selection criteria recommended above, might kick-start any future efforts in this area.

1 Introduction to the Phase Two Incremental Cost Study

This report presents the results of the second Incremental Cost Study (ICS Phase Two), following the ICS Phase One. The report describes the methods and results of the follow-on study commissioned by the Evaluation, Measurement and Verification Forum Research 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 (PAs) 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, 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 RFP 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. Cost-effectiveness tests, however, 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 ICS Phase Two considered a total of 14 measures; 6 measures involved follow-on work from Phase One, 8 measures were new for ICS Phase Two. Six of the eight new measures were C&I and six measures were electric. Table 20, below, briefly summarizes all measures and their status.

Table 20. Summary of ICS Measures

Measure	Sector	Fuel	Application	Cost Type	Costs Provided
Task 1: Additional Work on Phase One Measures					
Combination Heat Hot Water	Res	Gas	ROB	Inc	X
Condensing On Demand Water Heaters	Res	Gas	ROB	Inc	X
Insulation, Attic, Cellulose	Res	Gas	RET	Inc	X
Residential Central Air Conditioning	Res	Electric	ROB	Inc	*
Air Sealing	Res	Gas	RET	Full	NP
Gas Boilers	C&I	Gas	ROB	Inc	NP
* Examined Premium Pricing Issues Only					
Task 2: New Measures					
Prescriptive Chillers	C&I	Electric	ROB	Inc	X
Dual Enthalpy Economizers	C&I	Electric	RET/NC	Inc, Full	X
Variable Frequency Drives	C&I	Electric	RET	Inc	X
Residential Ductless Mini-Splits	Res	Electric	RET/NC	Inc, Full	X
ENERGY STAR Ventilation Fans	Res	Electric	ROB/NC	Inc, Full	X
Commercial Refrigeration Compressors	C&I	Electric	RET, ROB	Inc	NP
Boiler Controls	C&I	Gas	RET/NC	Full	NP
Energy Management Systems (EMSs)	C&I	Gas/ Electric			NP
KEY: RET = Retrofit, ROB = Replace on Burnout, NC = New Construction, NP = Not Pursued, Inc = Incremental					

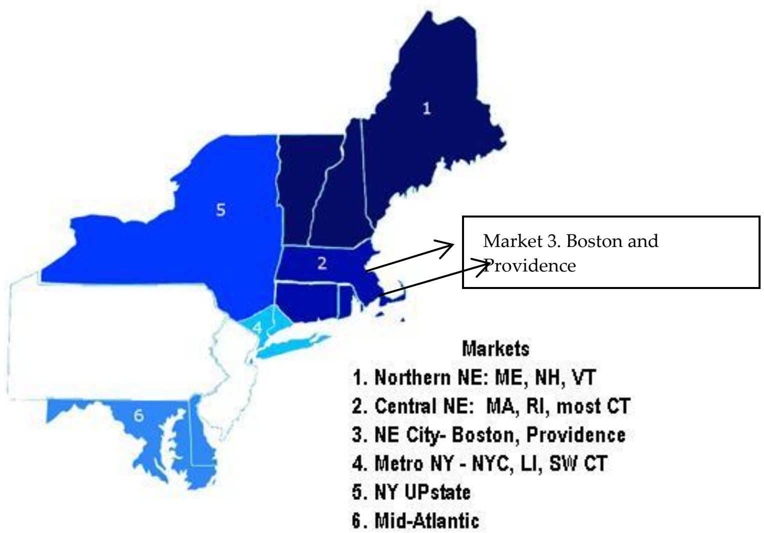
Navigant presents additional research requested by the Subcommittee, referred to as Task 1, including the following:

- Condensing On Demand water heaters
- Combination heat and hot water units
- Cellulose-insulated attics
- Commercial boilers
- An investigation of premium pricing centered on residential AC

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 shows the six regional markets identified.

Figure 2. ICS Regional Markets



Source: Data from RS Means

*BCF is used to normalize data collected from different markets for analysis on a single platform.

1.1 ICS Research Methodology and Process

Navigant collected and analyzed data for ICS Phase Two in the same way and using the same process as we did for the Phase One study. The full methodology is detailed in Section 4 of this report. Briefly, Navigant used the following process for all ICS Phase Two measure research:

1. For Task One follow-on measures, reviewed measure characterization from Phase One research and updated if needed
2. For Task Two new measures, created new characterizations and reviewed them with the relevant TAG
3. Employed a standard protocol for collecting materials and labor costs, built on the Phase One protocols, with adjustments for particular measure characteristics or costing as needed
4. Obtained data from program administrator databases to the extent possible for each measure, describing characteristics of measures installed and installer contact information, but not costs
5. Developed interview quotas based on achieving 90/10 precision[14] and time required per completed interview (based on ICS Phase One experience) and budget resources. Quotas

[14] 90/10 precision means at the 90% confidence interval, results will be within ±10% of the analyzed costs.

assumed equal interview distribution from the six markets for each measure. Researchers attempted to interview installers from each market, which was generally not possible. Not all program administrators offered the project measures and for most measures Navigant received program data from only a limited number of program administrators. Conducted phone interviews of installers for each measure, using a combination of program administrator contact information (some of that from websites) and where needed, cold calling. Navigant completed 104 interviews. In order to achieve that number, Navigant staff made 1,015 calls.

6. Obtained some limited additional data from program administrator invoices, Internet costs, and prior studies
7. Placed all data for each measure on a single analysis factor using updated RS Means factors to create Base Cost Factor results for each measure
8. Using RS Means updated factors and updated inflation costs, generated preliminary materials, and labor costs for each measure for each market. Preliminary costs were closely reviewed by the TAGs and adjusted in response to TAG comments and issues. Technical Advisors included program administrator staff, implementation contractors, and NEEP consultants, who effectively critiqued the costs and helped Navigant present costs in a manner most useful to program administrators, planners, and evaluators. . The Phase Two review process (measure characterization and preliminary cost reviews) was both broader and deeper than the Phase One review process experience. NEEP, Subcommittee members, Technical Advisors and Navigant invested increased time and effort, leading to very robust Phase Two results. Reviewed Task 2 measure characterizations and preliminary costs for all measures with technical advisors (TAGs), obtaining more outside reviewer input and more rigorous critiques than in Phase One

Note: Only BCF costs are shown in the executive summary and the report body. Costs for all markets are shown by market and measure in Appendix A.

1.2 *Incremental Cost "Shelf Life"*

Navigant and others have noted that incremental cost studies are often difficult to implement and expensive to underwrite. The ICS Phase Two's sponsored research is one way to mitigate the expense by pooling resources across a number of program sponsors throughout the Northeast and Mid-Atlantic states.

A further question is, once these costs are determined, what can we expect about their shelf life? How long can these costs be considered reliable before further investigation is required? There are several factors that can affect shelf life, such as the following:

» Technology changes
» Changes in the market appeal and purchase of appliances and equipment
» Changes in manufacturing that reduce costs (e.g., scaling up from increased demand, automation, and use of less expensive materials)

One example of expected change was found in On Demand water heaters. In the ICS Phase One, the presence of condensing units in the marketplace was believed to be quite limited. A year later, condensing units have essentially become the marketplace for this efficient technology. Residential Mini-Splits are another measure in which technology and market acceptance in the Northeast have changed greatly; single-room units were the most common configuration in the very recent past but multi-room units are becoming much more common and should be studied further. Other measures researched in this study are not expected to undergo dramatic changes. To assist NEEP and the project sponsors, Navigant has estimated the likely stability of the costs reported in this study. We have done this by consulting with informed individuals within the industries and within Navigant's own energy group. Table 21 shows expected shelf life for all study measures, including Task 1 and Task 2.

Table 21. Measure Cost Shelf Life

Measure	Expected Cost Life	Comments
Task 1 Measures		
Combination Heat/Hot Water Units	Frequent	Expect increased penetration. Combination units are becoming an increasingly cost-effective option compared to conventional boiler/water heater systems for many homeowners.
Condensing On Demand Water Heaters	Medium	Surveyed products already meet 2015 standard.
Attic Insulation-Cellulose	Stable	No major changes expected in the next 3-5 years.
Residential Air Conditioning	Medium	Standards change may bring down manufacturing costs through increased scale.
Task 2 Measures		
Prescriptive Chillers	Medium	
Economizers	Medium	
Variable Frequency Drives	Medium	
Residential Ductless Mini-Splits	Frequent	Expect increased penetration of heating/cooling units in cold climates and multi-room units.
ENERGY STAR Ventilation Fans	Medium	No updated ENERGY STAR specs currently in development. The most recent ENERGY STAR spec, version 3.2, was updated April 2012.
Commercial Refrigeration Compressors	Started but not pursued[15]	
Commercial Boiler Controls	Not Studied	
Energy Management Systems	Not Studied	
Key		

[15] The sponsoring program administrator most active on this measure determined in summer 2012 that its own measure characterization required review and update, putting the cost study for the measure on hold. Later, the PA recommended not pursuing cost work because the measure needed re-thinking and re-packaging.

Measure	Expected Cost Life	Comments
Stable - No expected Technology or Standards changes Update for annual inflation only next 3-5 years		
Medium - Codes/Standards changes possible 1-3 years		
Frequent - Market/Technology changes will affect measure characterization/costs in 1-3 years.		

1.3 Use of the Incremental Cost Study

The 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 ICS 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 efficiencies. 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. To aid study users, we have estimated and indicated the likely persistence of the costs determined in this study for factors besides normal inflation adjustments.

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; however, 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.

Finally, how efficient equipment is specified may vary among jurisdictions or change over time within jurisdictions as a whole or by individual program administrators. 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.

In addition to the tables contained in this report, the complete workbooks for each measure will be provided directly to the Subcommittee and also will be available on the EM&V Forum website.

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.

2 Task 1: Additional Research on 2010-2011 Phase One Measures

2.1 Introduction

Following the ICS Phase One, the EM&V Subcommittee determined that further cost research in five areas was desirable for a variety of reasons, including the following:

- Better understanding of "premium pricing" on residential central AC and other appliances
- Additional data collection for On Demand water heaters and combination heat and hot water units to reflect changes in the markets for the former and better understanding of a seemingly bifurcated market for the latter
- Review of protocols for residential air sealing in existing homes
- Review baseline and decreasing incremental costs for commercial boilers

Table 22 describes the measures, the issues, and the resolution for each measure.

Table 22. Measures, Issues, and Resolutions

Measure	Issue	Results
Combination Heat/Hot Water	» Understand bifurcated market, pricing concerns on a new measure » Base Case – Is replace on boiler burnout most appropriate? Should cost of hot water replacement heater be included?	» "Bifurcated market" actually included units found to be non-compliant with ENERGY STAR. Removed those units and bolstered original data set with additional interviews for compliant equipment. » Result: Cost increases of 46% » Base case remained the same for the ICS but other scenarios could be developed.
On Demand Water Heaters (moved from Task 2 to Task 1)	» First ICS reported non-condensing units. ICS Phase Two researched condensing units.	» Supplemented 2011 cost data with additional interviews
Attic Insulation using Cellulose	» Attic Insulation Disaggregated by material type » Refine labor costs	» Completed interviews on cellulose open blow attics – Costs established per sq. ft. all-in. » Costs not applicable to MA insulation pricing*

Measure	Issue	Results
Residential AC	» "Premium Pricing", AC and other appliances » "Big Box" participation	» Res AC – could identify perhaps 2-2.5% "non-energy" manufacturing costs but bounds of energy/non-energy costs not clear. Expect this problem to impact similar analysis for other appliances and equipment. » Big-box interview attempts not fruitful – interviewed 9 installers on customer priorities and dealer influence on customer purchase decisions » Result –Discussion on topic below and full memo attached as Appendix B
Air Sealing	» Validate protocols in existing buildings for baselines and results. Concern raised about compliance with ENERGY STAR protocols	» Determined that ICS protocols were appropriate for existing buildings. ENERGY STAR protocols apply only to new construction. » Result: No further research required
Commercial Boilers	» Baseline question » Concern on decreasing cost increments, suggesting additional data required to bolster ICS findings » Concern the ICS reached the "right" respondents at the companies interviewed	» Question: Did Navigant collect full costs for the baseline? answer: yes. » Decreasing cost increments found to result from manufacturer small changes such as tweaking controls » Result: No further research required

- MA has an insulation fee schedule developed under a separate methodology. Additional explanation provided in section three of this report.

2.2 *Task 1 Market Characterization*

Table 23 shows baseline and efficient measures studied, efficiency metrics, cost basis, and other characteristics of the three measures on which additional cost research was conducted.

Table 23. Task 1 Measure Characterization

	Residential Combination Heat & Hot Water	Condensing On- Demand Water Heaters	Residential Insulation Cellulose
Application	ROB	ROB	RET/NC
Size Range/ Products Covered	< 65,000 Btu/h	Residential buildings 180-199M BH	» Attic » ~1,000 ft^2
Efficiency Metric	CAE[16]	EF	R-Value
Baseline	80% AFUE boiler	82	No Insulation
Efficiency Level(s)	90, 91, 93, 95 CAE	94, 95, 96 EF	» Attic: R-19, 38, 60
Cost Basis	$/Unit	$/Gal/EF	$/ft^2
Material Analysis	Regression	Regression	Regression
Labor Analysis	Weighted Average	Arithmetic Mean	Weighted Average

As noted in Section 1.1 above and described in greater detail in section 4 of this report, Navigant reviewed characterization with TAG members, collected data using the interview technique developed in Phase One, and sought review and comment from TAG members for each of the Task 1 measures. Table 24 shows the organizations contacted and responses.

[16] Ratings for Combined Heat and Hot Water are expected to change under federal standards.

Table 24. Task 1 Measure Reviewers, Comments, and Responses

Task 1 Measure	Organization	Response?	Comments
Combination Heat and Hot Water	VEIC	No	
	NSTAR	No	
	BGE	Yes with PEPCO	No issues with costs
	PEPCO	Yes with BGE	No issues with costs
	Berkshire Gas	Yes	Costs are now in line with market.
On Demand Water Heaters	BGE	Yes with PEPCO	ICF for BGE and PEPCO - Overall ok
	NYSERDA	Yes	Provided some recent cost data - added to analysis set - no net cost change
	PEPCO	Yes with BGE	ICF for BGE and PEPCO - Overall ok
	CSG	Yes	Review by CSG found costs to be appropriate.
	National Grid	No	
	VT Gas	No	No review time available
	CSG	Yes	Review by CSG (for BGE) found costs to be appropriate.
	National Grid	No	
	NYSERDA	Yes	Costs deemed reasonable
	PEPCO	Yes with BGE	Costs OK
	VEIC	No	
	National Grid	Yes	Reviewed for MA only. Concern about MA insulation. Navigant noted MA special situation price list.
	Nu	No	

Task 1 Measure	Organization	Response?	Comments
	NSTAR	Yes	CSG found differences between MA predetermined prices and market-level costs generated by ICS Phase Two. Different methods and market. No net changes

2.3 *Combination Heat and Hot Water*

2.3.1 General Overview

Combination Heat and Hot Water units (combination units) include a potable water heater within a modulating boiler unit. This measure is optimal where limited space exists for two separate units.

2.3.2 Research Rationale

The 2011 Combination unit analysis raised several questions that warranted a follow-on research effort in 2012. First, the 2011 data showed a bifurcated market representing two distinct price ranges; one range was on a par with the residential boiler market and the other range included exclusively one manufacturer's units at significantly lower cost. We learned that the line of lower cost units did not conform to ENERGY STAR standards and dropped them from the analysis. Second, the 2011 analysis did not include raw data collected from the Mid-Atlantic region, so we targeted Maryland to make sure it was properly represented. Last, this year we inquired directly about typical baseline scenarios when speaking with contractors to better understand when homeowners decide to install combination units.

2.3.3 Measure Characterization

This measure covers residential combination heat and hot water units with capacities less than 200 MBH. The baseline was a standard residential boiler with an efficiency of 80 AFUE. The baseline scenario also technically includes a standard storage tank water heater; however, the water heater is not included in the baseline equipment costs. This analysis assumes that a homeowner's boiler fails and the homeowner 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 (CAE). The analysis considered efficiency-level scenarios of 90, 91, 93, and 95 CAE, as shown in **Error! Reference source not found.**.

Table 25. Efficiency-Level Specifications for Combination Heat and Hot Water 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	93 CAE
High-efficiency Tier 4	95 CAE

2.3.4 Data Collection

Navigant received contact information from NSTAR for 20 participating contractors in Massachusetts and an additional list of model numbers for combination units installed recently in Berkshire Gas territory. Navigant supplemented this data by calling all of the contractors that we interviewed for residential boilers and combination units in 2011. We attempted to use the BGE online directory of contractors to target Maryland, with mixed results. Many contractors listed did not install combination units. Lastly, we placed cold calls to contractors we found through Google searches in areas that were not covered by any other data source, as shown in **Error! Reference source not found.** and **Error! Reference source not found.** below.

Table 26. Program Administrator-Supplied Information for Combination Heat and Hot Water Units

NEEP Member	Information	States Represented
NSTAR	20 contractor names, addresses	MA
Berkshire Gas	Combination Unit Model Numbers	MA
BG&E	Online directory of 42 contractor names and phone numbers	MD

Table 27. Call Outcomes for Combination Heat and Hot Water Units

Call Outcome	Number of Calls Placed by Navigant	% of Total
Interviews Completed	10	19%
Interviews Declined (Not willing OR not informed about combo installations)	8	15%
Unable to Reach (Did not answer or return voicemail)	44	76%
Total	62	100%

2.3.5 Results

Cost results are shown in **Error! Reference source not found.** below. The additional research done in the ICS Phase Two resulted in incremental cost increases averaging 28% across the range of sizes and efficiencies. This increase is clearly a result of removing the lower cost units that were found to be non-compliant with ENERGY STAR standards.

Table 28. Combination Heat and Hot Water Incremental Costs

2012 Results - Incremental				
Size (MBH)	**BCF - Installed Cost ($/Unit)**			
	90 CAE	**91 CAE**	**93 CAE**	**95 CAE**
110	$1,780	$2,059	$2,619	$3,179
120	$1,836	$2,115	$2,675	$3,234
126	$1,869	$2,149	$2,709	$3,268
150	$2,004	$2,283	$2,843	$3,402
199	$2,278	$2,558	$3,117	$3,677

Baseline assumes Replace on Burnout of a standard hot water residential boiler rated at the Federal Minimum Annual Fuel Utilization Efficiency (80 AFUE).

2.3.6 Issues/Resolutions

The main issue that arose during the combination unit analysis was regarding the baseline scenario. Navigant proposed a specific replace-on-burnout replacement scenario during the 2010 ICS effort that assumed a combination heat and hot water unit would only be installed after the home's boiler failed. Therefore, the 2010 reported costs were the difference between the cost to install a combination heat and hot water unit and the cost to install a new baseline boiler. Navigant's 2010 reported incremental costs did not look at scenarios where replacements are made after the water heaters fail (but the boiler is still functioning) or where both the boiler and water heater fail.

Navigant's 2012 ICS effort found that the replacement scenarios observed by NEEP's constituents are not homogeneous across the entire NEEP territory. For example, some utility partners expressed interest in developing incremental costs for scenarios where both the existing boiler and water heater fail. Therefore, in order to provide NEEP and its constituents with cost data in the most efficient manner, Navigant shows full costs for combination heat and hot water units in the project workbook. The users of this data may take the full costs for combination heat and hot water units, water heaters, and boilers and develop specific scenarios that reflect the activities within their service territories. Full data are found in the measure workbooks that accompany this report.

2.4 *Condensing On Demand Hot Water Heaters*

2.4.1 Research Rationale

On Demand water heaters were a measure in the first ICS. In mid-2010, when the measure list was developed, the Subcommittee believed that condensing units were not a large part of the market for this measure and the research focused on non-condensing units. Data was also collected and reported on higher efficiency condensing units in the first ICS. In ICS Phase Two, the Subcommittee requested further exploration focused on condensing units, categorizing this measure as a "new", Task 2 measure. However, Navigant reviewed its characterization and collected data and recommended that supplemental data collection and analysis would be sufficient to provide up-to-date costs.

2.4.2 Measure Characterization

Residential condensing 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 technical reference manuals (TRMs) published by NEEP sponsors and other jurisdictions, as shown in Table 25. 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 non condensing water heaters within NEEP territory, and the higher efficiency levels represent condensing models.

Table 29. Efficiency-Level Specifications for Condensing On Demand Water Heaters

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 the following 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
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.

2.4.3 Data Collection

2.4.3.1 Data Sources

Navigant used contact information from Baltimore Gas & Electric, Yankee Gas, NSTAR, Gas Networks, National Grid, and Northeast Utilities to conduct interviews with contractors. **Error! Reference source not found.** presents the information supplied and the states represented for each of the data sets provided by NEEP members. Navigant used this contractor information to place calls with contractors around the NEEP territory who may 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 30. Program Administrator-Supplied Information for Condensing On Demand Water Heaters

NEEP Member	Information Supplied	States Represented
Baltimore Gas & Electric	60 contractor names and phone numbers	MD
Yankee Gas	48 contractor names and phone numbers	CT
NSTAR	20 contractor names and phone numbers	MA
Gas Networks	1,155 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.

2.4.3.2 Data Collection

Navigant called a total of 204 contractors and completed 33 interviews in the data collection process. **Error! Reference source not found.** 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. Twenty-one contractors declined, typically because they did not want to disclose pricing information. The data includes both ICS Phase One and ICS Phase Two efforts; the ICS Phase Two interviews are indicated as "new" calls.

Table 31. Call Outcomes for Condensing On Demand Water Heaters

Call Outcome	Number of Calls Placed by Navigant	% of Total
Interviews Completed	30 (12 new)	16%
Interviews Declined	21 (10 new)	10%
Unable to Reach (Did not answer or return voicemail)	153 (84 new)	74%
Total	204 (103 new)	100%

2.4.4 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 52 data points, including 6 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.
Because ICS Phase One and ICS Phase Two data were combined, ICS Phase One data was multiplied by an inflation factor of 1.03 to convert the values to current dollars.

2.4.5 Results

The incremental cost results for On Demand water heaters are presented in **Error! Reference source not found.** and **Error! Reference source not found.**. The standard On Demand water heater is a non-condensing unit, which is why it is the lowest efficiency level for On Demand units 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 32. Condensing On Demand Water Heater Incremental Costs

	Base Cost Factor Incremental Cost ($/Unit)			
Size (MBH)	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,729	$2,506	$2,557	$2,608
180	$1,637	$2,415	$2,466	$2,516
180	$1,564	$2,342	$2,392	$2,443
199	$1,665	$2,443	$2,493	$2,544
199	$1,528	$2,305	$2,356	$2,407

Table 33. Condensing On Demand Water Heater with Additional Installation Costs

Size (MBH)	Base Cost Factor Incremental Cost ($/Unit)			
	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$2,116	$2,894	$2,944	$2,995
180	$2,024	$2,802	$2,853	$2,903
180	$1,951	$2,729	$2,779	$2,830
199	$2,052	$2,830	$2,881	$2,931
199	$1,915	$2,693	$2,743	$2,794

2.4.6 Issues/Resolutions

In some interviews, contractors were not comfortable providing detailed cost breakdowns for materials and labor, and preferred to quote an overall cost. In these cases, Navigant used the average ratio of material cost to labor cost calculated from ICS Phase One data to estimate material and labor costs.

Through the interviews, installers noted that the major hurdle in installation of On Demand water heaters is installation of a larger gas line and related technical and inspection requirements. This has the potential to significantly extend the time needed to complete an installation if an inspection cannot be scheduled in a timely manner.

Technicians also indicate that overall savings are eroded by annual maintenance required to prevent buildup in heaters. Homeowners experience extended payback periods due to these recurring costs of operation.

2.5 *Insulation*

2.5.1 Research Rationale

The initial ICS examined several insulation types and scenarios, including cellulose, fiberglass, and foam insulation, installed in attics, walls, basements, and rim joists. That study attempted to separate material and labor costs for each of those scenarios yet found it difficult to do so as installers are not comfortable with or not accustomed to dissecting the material and labor components of their pricing. In this market, contractors typically develop and quote on a square foot basis for a given R-value or depth of insulation for a given insulating material.

The Subcommittee requested that Navigant narrow its focus to cellulose insulation in “open blow” attics, a very common circumstance and a way of reporting costs that the contractors are more likely to be able to understand (cost per sq./ft. basis). Navigant examined the costs of adding R38, R49, and R60 cellulose. For this measure, as with other measures, Navigant sought assistance from program administrators in the nine-state study area to provide leads to installers participating in current energy efficiency programs operated by program administrators. After collecting and analyzing costs through contractor interviews, Navigant was able to examine one program administrator’s database of installed costs for contractors that the study team interviewed. This review served as a cross-check on the costs reported by installers.

The incremental cost numbers for this measure are relevant to each of the states supporting the study with the exception of Massachusetts, which has a unique situation in this market. In all the states studied, except Massachusetts, insulation contractors are responsible for recruiting participants for insulation work. Massachusetts program administrators recruit residential participants through their jointly operated Mass Save gateway and assign participating insulation contractors to do work at a preset price schedule.[17]

Because of this special situation, the research team did not collect or analyze Massachusetts insulation installer data and does not suggest that the overall market data for this measure is applicable to the Massachusetts market.

2.5.2 Measure Characterization

This insulation analysis covers only blown-cellulose attic insulation applications. The baseline for insulation is no insulation installed or existing levels of insulation. The scenario does not have a cost consequence for any particular existing insulation value. Based on review of federal recommendations and several TRMs published by NEEP sponsors, efficiency levels are defined by R-value, as Table 34 shows.

Table 34. Efficiency-Level Specifications for Attic Insulation with Cellulose

Attic Existing Insulation Level	Added R-Value	Final R-Value
Any, presuming addition of insulation is recommended	R-38, R-49, R-60	R-38, R-49, R-60

2.5.3 Data Collection

Navigant received contact information provided by Connecticut Light and Power (CL&P) (NU) and BG&E to conduct interviews with contractors. Additionally, the team collected contact information for New York contractors via the NYSERDA website. Table 35 presents the information supplied and the states represented for each of the data sets 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.

[17] These contractors are paid according to a program administrator specific price list developed and typically updated yearly. Program administrators in Massachusetts perform a comprehensive macroeconomic analysis of the marketplace and cost drivers for the weatherization program in Massachusetts and derive cost data from sources such as the U.S. Bureau of Labor and Statistics and the U.S. Energy Information Administration. Changes in the marketplace such as the CPI, annual pay increases, annual gasoline increases, and regional benefits for private workers are also considered throughout the analysis. The Massachusetts program administrators also provide assistance for permit costs, marketing incentives, training subsidies, and other workforce development funds to the participating contractor base. Source: Massachusetts Program Administrators.

Table 35. Program Administrator-Supplied Information for Attic Insulation with Cellulose

NEEP Member	Information	States Represented
CL&P (NU)	21 contractor names, phone numbers	CT
NYSERDA	Online directory of contractor names and phone numbers	NY
BG&E	Online directory of 42 contractor names and phone numbers	MD

The Navigant team completed 14 interviews out of a total of 66 calls. Table 36 summarizes the call outcomes for insulation. To increase the success rate of placed calls, Navigant searched for each contractor on the Internet prior to placing the call. This enabled Navigant to screen out candidate contractors that clearly did not install blown cellulose in attics. Navigant placed calls to all those for which it was unclear, or to those who clearly did install blown cellulose.

Table 36. Call Outcomes for Attic Insulation with Cellulose

Call Outcome	Number of Calls Placed by Navigant	% of Total
Interviews Completed	14	22%
Interviews Declined	8	13%
Unable to Reach (Did not answer or return voicemail)	41	65%
Total	63	100%

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, did not want to share information, or did not have the information needed for the interview. This included four interviews for which the contractor was interested in assisting, but simply did not have the information ready, and was not willing to expend resources to collect the information.

2.5.4 Results

This measure presents the full cost per square foot on open attics insulated with cellulose, as shown in Table 7. The ICS Phase One considered a number of insulation measures but rolled up the costs of separate insulation materials and did not isolate the costs for cellulose. Navigant also had some concern about the labor costs reported with respect to “open blow” attics with cellulose insulation. Asking for labor costs for a variety of applications and materials may have unintentionally increased the labor cost for this straightforward application. In Phase 2, Navigant performed additional data collection for a typical “open blow” attic (no or few obstructions), re-examined labor costs, and presented the results on a $/sq. ft. insulated cost basis. The costs presented below assume no or negligible existing attic insulation.

Table 36A. Attic Insulation Using Cellulose

Blown Cellulose Attic Insulation	Base Cost Factor - Installed Cost ($/SF)		
	R38	**R49**	**R60**
Material Costs	$1.15	$1.24	$1.32
Labor Costs	$0.77	$0.77	$0.77
Total Installed Cost	**$1.92**	**$2.01**	**$2.10**

The incremental cost numbers for this measure are relevant to each of the states supporting the study with the exception of Massachusetts. Massachusetts has a unique situation in this market. In all the states studied, except Massachusetts, insulation contractors are responsible for recruiting participants for insulation work. Massachusetts program administrators recruit residential participants through their jointly operated Mass Save gateway, and assign participating insulation contractors to do work under a standard fee schedule developed by program operators using a separate methodology.

2.5.5 Issues/Resolutions

Three issues arose during interviews; while none of these issues prevented Navigant from collecting valuable information, additional study of these factors could provide improvements for future studies:

- Contractors typically quote on a square foot basis for a given R-value or depth of cellulose insulation instead of on a time and materials basis as contractors often do for other measures. As a result, it is often difficult for contractors to accurately provide data on the split of the total cost that is for labor versus materials (and markup). The approach Navigant followed for ICS Phase Two provided substantial improvements from ICS Phase One; however, some contractors still found it challenging to understand how to answer questions. Some felt most comfortable giving an approximate breakdown of labor versus materials on a percentage basis, rather than individual costs for each component. In future studies, interviewers may gain value by spending more time trying to better identify the right person to speak with who could help untangle the various cost components more clearly.
- Contractors rarely install blown cellulose by itself. A best-practice job will include air sealing, addition of soffit vents, baffles, and insulation "extras" such as recessed-light boxes. For many contractors, it is difficult to provide clear costs for just blown cellulose since it is often part of a more comprehensive "weatherization" job. During some interviews, Navigant found it difficult to discern whether the contractor was providing costs for weatherization versus just insulation.
- During the economic downturn, Navigant found that few contractors do large numbers of new construction installations. Accordingly, the team collected very few data points on new construction costs. For greater statistical confidence on new construction, more effort must be put into identifying new construction insulation installers.

A fourth issue arose during the review process. Program administrators raised a concern that contractors might be inflating their costs in their responses to Navigant and asked for corroboration in the form of invoice reviews. One program administrator in a state from which significant numbers of interviews were completed provided implementation contractor database records with costs for the contractors interviewed. Navigant was able to compare its collected costs with the database costs and

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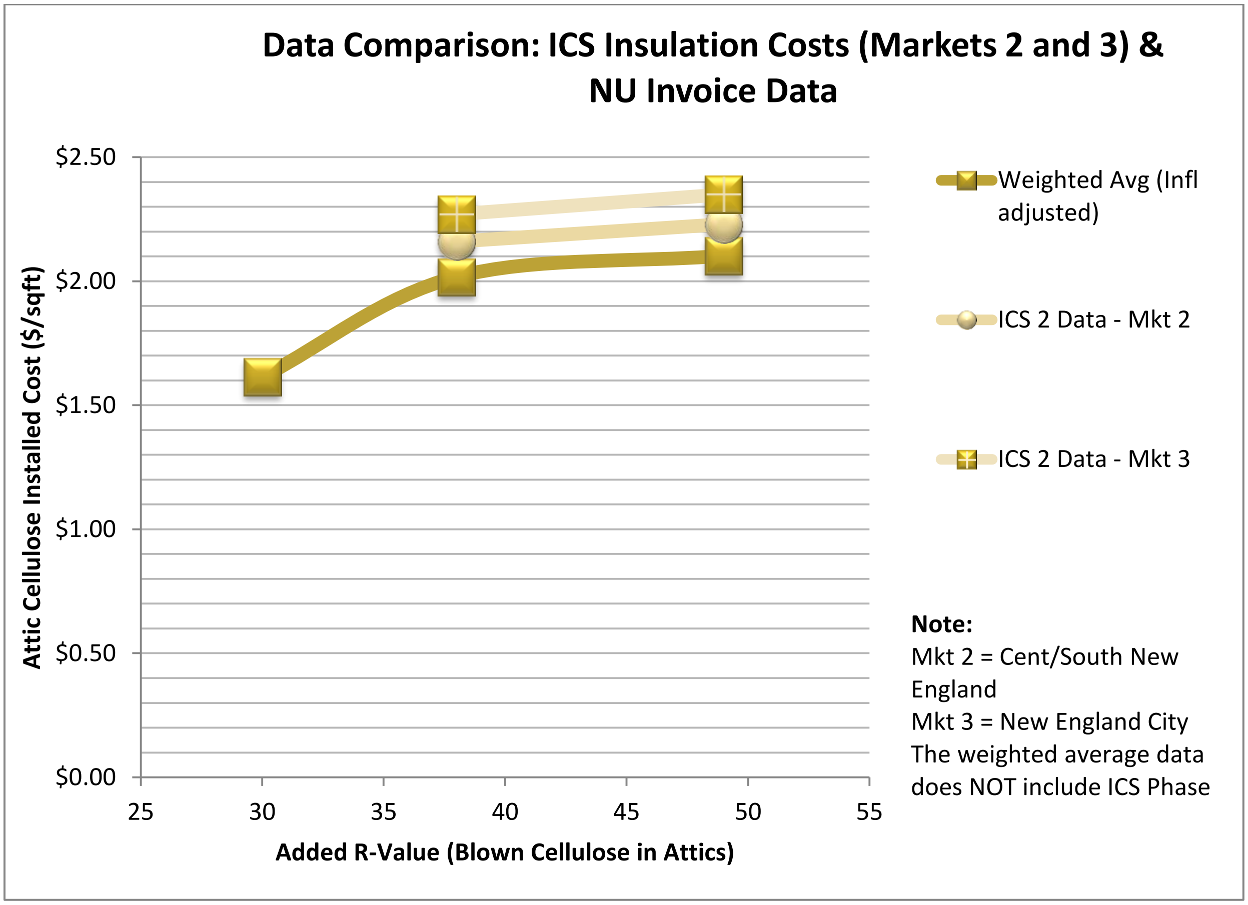
found in most cases there was close agreement, comparing the weighted average of contractor costs to the Phase Two results, as shown in Figure 3.

Figure 3. Comparison of ICS Attic Insulation with Cellulose Costs to Contractor Invoices for Two Markets



2.6 *Premium Pricing in Residential Air Conditioning and Other Consumer Appliances*

Navigant has researched the extent and cost impacts of premium non-energy-saving features in residential central AC units. The issue of concern here is that cost-effectiveness is being affected by the inclusion of costs that do not contribute to energy efficiency but are taken into account in the Total Resource Cost (TRC) test. Navigant also considered whether this phenomenon might lead to a premium pricing metric or for residential AC. A robust metric would potentially apply to other consumer appliances where premium features increase price without increasing the unit's energy efficiency
This work resulted from interests of the Regional EM&V Forum Research Subcommittee that arose in the course of the ICS Phase One, conducted by Navigant. In the Phase Two study, the Subcommittee directed Navigant to investigate the following questions:

1. Are energy-efficient central AC systems packaged with additional features that add to the unit cost and incremental cost between standard and efficient units?
2. Can the costs of identified features be quantified, enabling program administrators to obtain a clearer understanding of the costs of increasing energy efficiency from SEER 14.5 to SEER 15 and above?
3. What can we say about premium pricing that may affect the costs of other types of energy-efficient consumer appliances? Can we establish a premium cost metric or methodology that would lead to reliably quantifying premium costs?

Given the increasing cooling load in the Northeast resulting from first-time installation of residential central AC, as well as increased purchases of room AC units, the penetration of highly energy-efficient central AC becomes increasingly important. A 2003 study on the impacts of climate change and electricity consumption noted that:

> *Although the temperature-induced increases in market penetration of air conditioning had little or no effect on residential energy consumption in cities such as Houston (93.6% market saturation), in cooler cities such as Buffalo (25.1% market saturation) and San Francisco (20.9% market saturation), the extra market penetration of air conditioning induced by a 20 percent increase in CDD[18] more than doubled the energy use due to temperature alone[19].*

Central AC systems are long-lived measures. Program planning typically assumes measures lives of around 15 years[20] but units can function well in excess of 20 years. Customers making first-time purchases in existing homes that previously were not centrally cooled are making a considerable investment. Such customers can be expected to be very sensitive to first cost. But they may also consider convenience and various premium features for a system they expect to live with for many years. Dealers have an opportunity to increase their profits by emphasizing the relatively small additional cost of mid-line and top-line units, if customers consider those costs over 15 years. Thus, dealer recommendations and customer preferences can affect residential cooling energy use over an extended period. However, it's not clear from this brief study what customers are actually buying. The dealers we spoke with overwhelmingly found customers to be focused on cost, first, and mentioned few features that would fall into the premium set, mainly noise reduction.

The full premium pricing research memo is found in Appendix B.

2.6.1 Approach

This paper presents the results of Navigant's investigation and analysis of residential AC premium features. Navigant's approach to assessing the three questions presented included a close look at

[18] CDD = Cooling Degree Days. Based on the day's average temperature of minus 65°F, relating to the demand for air conditioning. Source: National Weather Service.
[19] David J. Sailor and A.A. Pavlova. 2003. "Air Conditioning Market Saturation and Long-Term Response of Residential Cooling Energy Demand to Climate Change." *Energy* 28: 941-951.
[20] Michigan MEMD Database for deemed measure savings.

manufacturer marketing efforts to identify the premium features. This report also explores the extent to which AC systems are packaged with additional features.
Following the analysis of premium features and how they are bundled, Navigant conducted brief interviews with nine Massachusetts installers to assess customer demand for these premium features.

2.6.2 Premium Features

Through investigation of manufacturer marketing materials, Navigant identified four premium features:

- Durability and Appearance
- Comfort and Noise Reduction
- Improved Warranty
- Improved Controls, Sensors, and Alarms

2.6.3 Findings

Question 1. Are energy-efficient central AC systems packaged with additional features that add to the unit cost and incremental cost between standard and efficient units?

Answer 1. Yes, they are.
The study found that residential central AC systems are packaged with a variety of non-energy features that vary from manufacturer to manufacturer. Non-energy features include aspects such as the following:

- Durability and Appearance
- Comfort and Noise Reduction
- Improved Warranty
- Improved Controls, Sensors, and Alarms

Manufacturers typically offer a base tier, a mid-tier, and a top tier. Some premium features are introduced in the mid-tier units and further enhanced in the top tier, where additional features are also added. Manufacturers often reserve premium features for higher efficiency units to differentiate their product offerings. Some features are not offered across a manufacturer's entire product range within a given efficiency rating. This makes isolating features as *premium* features more difficult.

Question 2. Can the costs of identified features be quantified, enabling program administrators to obtain a clearer understanding of the costs of increasing energy efficiency from SEER 14.5 to SEER 15 and above?

Answer 2. No, not with certainty at this time. While Navigant took a few different approaches to identifying costs associated with additional features, they could not be quantified with any level of confidence. Because of manufacturer bundling of premium features in higher efficiency AC units, dealers/contractors were unable to break out costs of specific premium features. Navigant's own earlier work for DOE focused on determining the costs of increasing efficiency standards and the manufacturing economies of scale that occur as the baseline is moved upward, and was not oriented toward the premium features. A review of "non-energy" features, conducted long after the tear-down analysis was completed, identified as much as 2.5 percent of manufacturing costs as "non-energy", including features "like sound blankets that are typically not found on entry-level units and whose purpose is 100 percent not related to energy efficiency."[21] The project team leader went on to say:

> "In short, there isn't much that a manufacturer throws at a central AC unit that isn't somehow efficiency related. Efficiency, size, and noise remain the main pillars of differentiation, as best as I can tell in a market where ***anything below 16 SEER has been pretty well commoditized (emphasis added)***, thanks to standards, rebates, and other incentives. For example, Carrier won't offer Infinity controls for systems that cannot (theoretically) reach 17 SEER."[22]

The comment about SEER 16 is significant. Currently, program administrators offer incentives on residential AC that exceeds 14.5 SEER. In a "thoroughly commoditized" market, manufacturers have made all the economies they can achieve and customers are seeking price and perhaps brand as the purchasing determinants. The question of the role of premium features, therefore, comes into play mainly at levels above the current standards.

The mix of features among the three tiers varies among the manufacturers; therefore, it is not possible to say a mid-tier unit always includes a particular non-energy feature, no matter who manufactures the unit.

Question 3. What can we say about premium pricing that may affect the costs of other types of energy-efficient consumer appliances? Can we establish a premium cost metric or methodology that would lead to reliably quantifying premium costs?

Answer 3. With the current research under this limited scope of work, Navigant was not able to develop a premium cost metric or approach. Further research taking other approaches may prove more fruitful in establishing premium cost factors.
A small number of supplemental interviews conducted in this study provide an anecdotal window into customer priorities but a more substantial customer sampling would provide a clearer picture. Dealers report that customer decisions are driven by price but dealers are quick to point to efficiency program

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[21] Constantin von Wentzel, Navigant Project Manager on DOE Appliance Regulation projects. personal communication, 8/17/2012.

[22] Constantin von Wentzel. personal communication, 8/17/2012.

rebates, which they believe move customers up the efficiency curve, meeting the program goals of increasing efficiency. A customer-centered study could probe these decisions further but with a different orientation from typical free-ridership/spillover studies. Questions might include the following:

- Do first-time customers, of whom there are increasing numbers in existing homes, approach the purchase of a central AC system in the same ways as customers replacing existing equipment?
- What are the priorities and preferences of each group?
- From the customer perspective, what makes the sale in a general way and what further makes the sale for the more efficient units and the most efficient units?
- Do contractor reports about the impact of incentives on customer efficiency choices hold up?

2.6.3.1 Broader Applicability of the Premium Pricing Question

We have seen examples of other consumer appliances, refrigerators, and clothes washers for two examples, in which higher and highest efficiency units are packaged with a variety of premium features. The research team considered how additional research on central AC and other appliances might help develop a metric for the premium feature cost. With regulator agreement, such a premium index could be used to discount the full cost of efficient appliances for the purposes of determining cost-effectiveness.

However, further investigations in this area may find that pricing of premium features for other appliances is similarly opaque and difficult to reliably quantify. Manufacturers are understandably loath to provide cost data. They operate in a highly competitive environment and have concerns about confidentiality. Manufacturer associations such as AHRI resist efforts to provide any shipment or sales data to efficiency researchers. Tear-down analyses are another potential research path that could shed light on the subject. These studies don't rely on manufacturer data and use robust materials, labor, markup, and other cost estimators to develop costs. A premium feature tear-down analysis would require the researchers to develop protocols that would clearly delineate energy from non-energy features. Currently, there is not protocol focused on that issue.

Further investigation is beyond the scope of this ICS. We believe, however, that further explorations, including developing a comprehensive research framework, could prove useful toward answering the central question of the extent to which non-efficiency features affect the cost and cost-effectiveness of efficient consumer appliances.

2.7 Commercial Boilers – Decision Not to Proceed

2.7.1 Research Rationale and Decision Not to Proceed

Commercial boilers were initially included in the ICS Phase Two over the following three concerns:

1. A concern as to whether or not the baseline was set appropriately
2. A concern that the incremental costs were found to decrease as efficiency increased. This concern suggested that additional data collection was needed to ensure the ICS results correctly portrayed the cost curve.

3. Concern about whether the study requested data from the correct individuals within the boiler manufacturers and installer responding companies

With regard to the first concern, a closer discussion with the Subcommittee member who raised the concern was found to actually be a concern about whether full measure costs were captured for both the baseline and efficient measures. A review of the data demonstrated that full costs had indeed been captured.

With regard to the second concern, that incremental costs decreased as efficiency increased, Navigant first reviewed the data collected for quality control and found no errors in the analysis. Navigant also reviewed the variance in data, confirming the finding that at the 90 percent confidence level, the variance in materials cost was 3.48 percent, the lowest observed variance for any measure in the study. Labor variances were higher but baseline and efficient measure labor variances were the same and the variance for both was well within the observed range for other project measures. Navigant then queried its Emerging Technologies group, which has completed a number of tear-down analyses of this sort of equipment, for further explanation. The resulting explanation was that in the case of commercial boilers, the higher efficiency levels are achieved through small equipment changes made to the already efficient units and tweaking boiler controls, essentially fine-tuning the boilers to reach higher efficiencies with the same basic configuration and characteristics found in lower efficiency units.
The concern about whether the most appropriate individuals had been interviewed apparently arose from a comment in the ICS report:

> *"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"*[23].

The comment did not cast doubt on the data collected through these interviews. It noted only that the companies contacted were larger and more complex than residential boiler companies and locating the most appropriate individual was more difficult, requiring a greater effort to complete the required number of interviews for that measure.

For the reasons cited above, Navigant recommended that no further cost research be done on this measure at this time. NEEP and the Subcommittee endorsed this recommendation.

2.8 Residential Air Sealing in Existing Homes and Decision Not to Proceed

Residential air sealing is an energy efficiency practice that has been used for more than 25 years in existing homes, first in low-income weatherization programs and later in initiatives offered by utilities and other program administrators. Over time, a number of cost approaches have been used in air sealing, including the following:

- Providing air sealing services for a set time period at a fixed cost

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[23]Navigant Consulting. *Incremental Cost Study Report Final*, p. 55, September 23, 2011.

- Measuring and costing pre- and post-air change/hour (ACH) values toward a specific reduction goal
- Costing air sealing on a square foot basis

Navigant reviewed a number of TRMs and determined to present costs on both square foot and ACH bases.

Following the completion of the ICS, a comment was made that the study had not followed the ENERGY STAR protocol and therefore further work was needed. Navigant reviewed ENERGY STAR protocols and found they existed only for residential new construction. There was no ENERGY STAR protocol for air sealing in existing homes. Navigant also confirmed that with at least one program administrator.

As a result of this preliminary investigation, Navigant recommended that further cost research on air sealing was not needed and NEEP and the Subcommittee concurred.

3 Task 2: New Measures for ICS Phase Two

3.1 Introduction

For Phase Two, the Subcommittee developed a list of new measures, under the rubric Task 2, focusing more on Commercial/Industrial measures. The Task 2 Measures included the following:

- Prescriptive Chillers
- Economizers
- Variable Frequency Drives (VFDS)
- Residential Ductless Mini-Splits
- ENERGY STAR Residential Ventilation Fans
- Commercial Refrigeration Compressors
- Commercial Boiler Controls
- Energy Management Systems

Of these measures, which are described in detail in Section three of this report, Navigant determined that three measures would not go forward, as shown in Table 37 below.

Table 37. Measures Not Studied

Measure	Reason for Not Proceeding
Commercial Refrigeration Compressors	Efficiency VT determined they set measure baseline too high – Navigant delayed research waiting for EVT. Now seems unlikely to go forward.
Commercial Boiler Controls	Navigant's characterization research revealed these controls now standard on new equipment. PA records show very few retrofits.
Energy Management Systems	This is really a custom measure. Navigant and Technical Advisors could not devise a usable prescriptive cost scenario that would be useful to a prescriptive program.

3.2 Research Process for Task 2 Measures

Navigant continued to collect and analyze data for ICS Phase Two as it did for the ICS Phase One. Methodology is detailed in section 4 of the report. Navigant used the following process:

1. Developed measure characterizations, submitted them to NEEP and TAG, aiming for at least two characterization reviews prior to commencing interviews.
2. Defined a standard protocol for collecting materials and labor costs, used across all measures, with adjustments for particular measure characteristics or costing. The Task 2 protocols differed little from the first ICS, except where there were specific issues to inquire about or the emphasis changed for a given measure.
3. Obtained data from program administrator databases to the extent possible for each measure, describing characteristics of measures installed and installer contact information but not costs. As with the first ICS, data sources were varied and sometimes inconsistent. Some program administrators did not offer a particular measure. Others were able to provide limited access to their databases. One program administrator provided electronic copies of invoices on three measures studied, which added to the body of costs but materials/labor breakouts were not generally included and in multiple measure projects, individual equipment costs were not always separated. In the end, most measures were represented by data from two or three program administrators. These data were not cost data but descriptions of measures and contact information for installers.
4. Conducted phone interviews of installers for each measure, using a combination of program administrator contact information (some of that from websites) and where needed, cold calling. Attempted to interview installers from each market, which was generally not possible. In general, Navigant found the same limited responses, getting completed interviews from about 10% of calls made.
5. Placed all data for each measure on a single analysis factor using updated RS Means factors to create Base Cost Factor results for each measure.
6. Using RS Means updated factors and updated inflation costs, generated preliminary materials and labor costs for each measure for each market.
7. Sought at least two reviews by the TAGs named by program sponsors. Where appropriate, Navigant adjusted costs in response to TAG comments and issues. (Only BCF costs are shown in this summary and the report body. All market costs are shown in Appendix A.) Reviewers, issues, and responses are shown in Table 38 below. Task 2 measure cost revisions elicited a number of comments, especially on mini-splits, chillers, economizers, and VFDs. Navigant made a number of adjustments to the analyses to present costs in the most useful fashion for program planners. Some issues raised would have been more helpful if raised during the characterization phase; earlier involvement of not just technical experts but program planners would improve the efficiency of the research model.

Table 38 shows the TAG members queried on preliminary Task 2 costs, their questions and issues, and Navigant responses.

Table 38. Comments and Responses on Task 2 Preliminary Costs

	Organization	Response?	Comments	Navigant Response
Prescriptive Chillers	BGE	No		
	EVT	Yes	Costs in line	
	National Grid - MA	No		
	NY DPS	Yes	Questions on demolition/installation costs, efficiencies covered	Replied with clarifications - no changes to workbooks
	National Grid - MA	No		
	NYSERDA	No		
	Northeast Utilities	Yes		
	NSTAR	No		
	PEPCO	No		
	NEEP	Yes	Qualifying efficiencies, capacity buckets, regressions	Added data higher efficiency units, revised presentation by efficiency, rearranged data to align with PA planning
	Other	No		
Residential Ductless Mini-Splits	BGE	No	n/a	n/a
	National Grid - MA	Yes	Cost data is comparable to National Grid pilot	None needed
	National Grid - NY	No	n/a	n/a
	NYSERDA	No	n/a	n/a
	NU	No	n/a	n/a
	NSTAR	No	n/a	n/a
	PEPCO	Yes	Regional adjustments error	Made correction in workbook
	EVT	Yes	EVT does not perform mini-split measures	n/a

	Organization	Response?	Comments	Navigant Response
	NEEP/ Emerging Tech Study	Yes	Include SEER values of non-perfect integers	Rounded values for both SEER and BTUs
			Need to better understand incremental cost vs. full cost	Developed increments from SEER 13 Baseline
			Why is analysis limited to single zones?	1. Based on what was found in PA databases 2. Installers hard to pin down on multi-head installations, which can be much more complex. Needs further work
			Methodology/logic for labor rate is unclear	Explained the methodology via comments
			Should investigate low-temp units	For a future study
	NEEP/ Emerging Tech Study	Yes	Incremental costs would be useful.	Developed increments from SEER 13 Baseline
			Unclear what is included in material costs	Material costs include the outdoor unit, indoor unit, and additional materials such as line set and condenser pad.
ENERGY STAR Ventilation Fans	EVT	Yes	costs ok, raised new construction issue	added new construction cost tables
	BGE	No		
	NYSERDA	No		
	Northeast Utilities	No		
	NSTAR	No		
	PEPCO	No		
VFDs	BGE	No		

	Organization	Response?	Comments	Navigant Response
	EVT	Yes	Costs in line	
	National Grid - MA	No		
	NYSERDA	No		
	Northeast Utilities	Yes	Concern about code - "dry bulb" baseline	adopted dry bulb baseline plus full costs
	NSTAR	No		
	For PEPCO, BGE	Yes	Provided additional cost data; concern about regression in workbook	Used the additional data; regression was only a reference and not used in the analysis
	PEPCO	No		
	NEEP	Yes	Concern about sizes presented	Expanded scope unit sizes to 600 HP
Dual Enthalpy Economizers	Rise Engineering	Yes	Concern about "sweet spot" distribution of sizes; concern costs were low	Cost review produced no changes
	BGE	No		
	EVT	No		
	National Grid - MA	No		
	NYSERDA	No		
	Northeast Utilities	Yes	Baseline should be dry bulb	Adopted dry bulb baseline plus full costs
	NSTAR	No		
	PEPCO	No		
	NEEP	Yes	Baseline should be dry bulb Discussion on regressions	Adopted dry bulb baseline plus full costs Resolved regression issues
	Rise Engineering	Yes	Baseline should be dry bulb	Adopted dry bulb baseline plus full costs

Table 39 summarizes the interviews and interview attempts for Task 2 measures.

3.2.1 Interviews

The research team developed interview quotas based on achieving 90/10 precision[24] and considering available time and resources. Quotas assumed equal interview distribution from the six markets for each measure. Researchers attempted to interview installers from each market, which was generally not possible. Not all program administrators offered the project measures and most measures received program data from only a limited number of program administrators. Conducted phone interviews of installers for each measure, using a combination of program administrator contact information (some of that from websites) and where needed, cold calling.

[24] 90/10 precision means at the 90% confidence interval results will be within ±10% of the analyzed costs.

Table 39. Summary of Interview Activity for Task 2 Measures

		Condensing On Demand Water Heaters	Attic Cellulose Insulation	Combination Heat/ Hot Water	Residential Mini-Splits*	ENERGY STAR Ventilation Fans**	Prescriptive Chillers	Economizers	VFDs
Interview Quota		10	10	10	15	15	16	16	16
Installer Completed Interviews									
Market	Regions	1	0	3	0	0	0	0	0
1	Northern New England (ME, VT, NH)	7	2	0	13	0	9	6	12
2	Central/Southern New England (MA (except Boston), RI, most CT)	0	0	0	0	0	0	0	4
3	New England City (Boston, Providence)	0	6	0	0	1	0	2	0
4	NY Metro (NYC, Metro, Suburbs, Southeast CT)	0	1	1	0	4	0	1	0
5	NY Upstate (Buffalo, Rochester, etc.)	1	5	6	0	0	5	0	0
6	Mid-Atlantic (MD, DE, DC)	1	0	3	0	0	0	0	0
Distributor Completed Interviews									
1	Northern New England (ME, VT, NH)	0	0	0	0	0	0	0	0
2	Central/Southern New England (MA (except Boston), RI, most CT)	0	0	0	1	0	0	1	0
3	New England City (Boston, Providence)	0	0	0	0	0	0	0	0
4	NY Metro (NYC, Metro, Suburbs, Southeast CT)	0	0	0	0	0	0	0	0
5	NY Upstate (Buffalo, Rochester, etc.)	0	0	0	0	0	1	0	0
6	Mid-Atlantic (MD, DE, DC)	0	0	0	0	0	1	0	0
Interviews Declined		10	8	31	1	7	16	6	7
Unable to reach contact (multiple calls, messages not returned, bad numbers, etc.)		84	41	183	41	38	141	97	210
Total Successful Calls		**9**	**14**	**10**	**14**	**5**	**16**	**10**	**16**

	Condensing On Demand Water Heaters	Attic Cellulose Insulation	Combination Heat/ Hot Water	Residential Mini-Splits*	ENERGY STAR Ventilation Fans**	Prescriptive Chillers	Economizers	VFDs
Total Unsuccessful Call Attempts	94	49	214	42	45	157	103	217
Total Call Attempts	103	63	224	56	50	173	113	233

* Distributor interview: National account manager arranged by NEEP TAG member.
** Interviews for labor only. Data not used due to high variations in labor required for projects.

3.3 *Prescriptive Chillers*

3.3.1 Characterization

Navigant examined costs for the following types of chillers:

- Air-Cooled Chillers
- Water-Cooled Scroll Chillers
- Water-Cooled Centrifugal Chillers

Based on conversations with technical advisors, a baseline unit is a standard chiller with the lowest efficiency rating available in the NEEP market. The measure-level unit is defined as a standard chiller with an efficiency rating greater than baseline. Efficiencies are defined in EER for air-cooled chillers and kW/ton for water-cooled chillers. All chiller costs were collected based on Full-Load chiller capacities. Some program administrators use part load data (IPLV) in their technical manuals; however, IPLV data is somewhat dependent on climate zone and installers did consistently provide IPLV data.

In addition, technical advisors suggested limiting the scope to 30-800 tons for Air-Cooled Chillers and 30-1,000 tons for Water-Cooled Chillers, and to consider both Water-Cooled Scroll and Water-Cooled Centrifugal type Chillers. Table 40 shows the chiller characterization.

Table 40. Chiller Characterization

Baseline Description	Standard chiller with lowest efficiency rating in NEEP market
Baseline Efficiency Levels	Air-Cooled: 9.6 EER Water-Cooled Scroll: 0.78 kW/ton (0-150 tons), 0.72 kW/ton (>150 tons) Water-Cooled Centrifugal: 0.64 kW/ton
Measure-Level Description	A Standard Chiller with an efficiency exceeding the baseline efficiency level for that chiller type
Measure Efficiency Levels	Air-Cooled: 9.90, 10.20, 10.52, 10.70 EER Water-Cooled Scroll: 0.72, 0.68 kW/ton (0-150 tons), 0.68, 0.64, 0.60 kW/ton (>150 tons) Water-Cooled Centrifugal: 0.60, 0.58, 0.54 kW/ton
Sizes	Air-Cooled: 50, 100, 150, 200, 400 tons Water-Cooled Scroll: 50, 100, 150, 200, 400 tons Water-Cooled Centrifugal: 100, 150, 200, 300, 600 tons
Distinguishing Features	Technology (Scroll vs. Centrifugal)
Installation Scenarios	Air-Cooled: Old chiller removal, new chiller ground installation Water-Cooled: Old chiller removal, new chiller rooftop installation, galvanized steel cooling tower Water-Cooled: Old chiller removal, new chiller rooftop installation, stainless-steel cooling tower

3.3.2 Data Collection

Contact information for installers and distributors was provided by National Grid, Baltimore Gas & Electric, and NSTAR and a total of 16 successful phone interviews were conducted. Additional data was collected from the DEER 2008 study, RS Means, and from invoices provided by National Grid for rebates issued in the last three years. All data not of 2012 vintage was updated using the most current applicable inflation factors.

3.3.3 Results

Table 41, Table 42, and Table 43 show the BCF cost results for three types of chillers. Full tables for each market are found in Appendix A. Within the same capacity chillers there are no incremental labor costs (e.g., a 150-ton chiller at 9.9 EER costs no more to install than the same size chiller at 10.7 EER). Full costs, including all installation, are found in the accompanying project workbooks.

Table 41. Air-Cooled Chillers (BCF) Incremental Cost

Air-Cooled Chiller Incremental Cost/Ton Estimates (Categorized by Efficiency (EER)) Baseline EER = 9.60					
Capacity (Tons)	**9.60 EER**	**9.90 EER**	**10.20 EER**	**10.52 EER**	**10.70 EER**
50	$0	$229	$457	$701	$838
100	$0	$114	$229	$350	$419
150	$0	$76	$152	$234	$279
200	$0	$47	$93	$143	$171
400	$0	$23	$47	$71	$85

Table 42. Water-Cooled Scroll/Screw Chillers

Water-Cooled Scroll/Screw Chiller Incremental Cost/Ton Estimates (Categorized by Efficiency (kW/Ton)) Baseline Efficiency: 0.78 kW/Ton					
Capacity (Tons)	**0.78 kW/Ton**	**0.72 kW/Ton**	**0.68 kW/Ton**	**0.64 kW/Ton**	**0.60 kW/Ton**
50	$0	$76	$126	n/a	n/a
100	$0	$38	$63	n/a	n/a
150	$0	$25	$42	n/a	n/a
200	n/a	$0	$61	$122	$183
400	n/a	$0	$31	$61	$92

Table 43. Water-Cooled Centrifugal Chillers

Water-Cooled Centrifugal Chiller Incremental Cost Estimates (Categorized by Efficiency (kW/Ton)) Baseline Efficiency: 0.64 kW/Ton				
Capacity (Tons)	**0.64 kW/Ton**	**0.60 kW/Ton**	**0.58 kW/Ton**	**0.54 kW/Ton**
100	$0	$73	$110	$183
150	$0	$49	$73	$122
200	$0	$37	$55	$92
300	$0	$61	$91	$152
600	$0	$30	$46	$76

3.3.4 Issues/Resolutions

Among the project sponsors, programs use varying standards for both size and qualifying efficiencies. Although the characterization was designed to accommodate as many sponsor efficiency programs as possible, technical reviewers noted that the range of air-cooled efficient units collected during the phone interviews did not meet the minimum qualifying efficiency in Massachusetts of 10.52 EER. Other program administrators use lower minimum efficiencies. This issue was resolved by collecting more data; there were several qualifying units in the added National Grid invoice data set. Other technical review comments focused on analysis and presentation of the cost data in a manner most consonant with the design of energy efficiency programs, and what unit sizes and efficiency levels would be presented in the results. These issues were resolved over the course of several phone conversations with technical advisors. The final results may not exactly match every current program's size/efficiency design but can be interpolated from the project workbooks.

3.4 *Dual Enthalpy Economizers*

3.4.1 Characterization

Based on conversations with technical advisors and internal subject matter experts, two baseline situations were selected:

1) Existing HVAC equipment with no economizer installed
2) Existing HVAC equipment with dry-bulb economizer installed

The measure-level unit is defined as an economizer with dual-enthalpy controls. The incremental paths for both situations are:

1) Install dry-bulb economizer and dual-enthalpy controls
2) Install dual-enthalpy controls on existing dry-bulb economizer

In addition, there are no efficiency levels, only baseline condition and an efficient measure. Reviewers recommended limiting the scope to units of 5 to 70 tons. Table 44 shows the characterization.

Table 44. Dual Enthalpy Economizers Characteristics

Baseline Description	Two scenarios: 1) Existing HVAC equipment with no economizer, 2) Existing HVAC equipment with dry-bulb economizer
Baseline Efficiency Levels	No defined efficiency levels
Measure-Level Description	HVAC equipment with economizer and dual-enthalpy controls
Measure Efficiency Levels	No defined efficiency levels
Sizes	5, 15, 25, 40, 70 tons
Distinguishing Features	Number of controls: single enthalpy vs. dual enthalpy
Installation Scenarios	Rooftop or inside building only

3.4.2 Data Collection

Contact information for installers and distributors was provided by National Grid, Baltimore Gas & Electric, and NSTAR and a total of 16 successful phone interviews were conducted. There was no need for additional data collection.

3.4.3 Results

Results for economizers are shown both as full and incremental cost, to represent the scenarios in which there was no economizer present and where a dry-bulb single enthalpy economizer was present, as shown in Table 45 and Table 46.

Table 45. Dual Enthalpy Economizers Showing Full Cost

Base Cost Factor Total Costs			
HVAC System Capacity (Tons)	Single Enthalpy Economizer	Dual Enthalpy Economizer Controls	Measure Total
5	$773	$178	$951
15	$1,267	$251	$1,518
25	$1,761	$324	$2,085
40	$2,502	$434	$2,935
70	$3,984	$653	$4,636

Table 46 shows the incremental cost of single enthalpy to dual enthalpy.

Table 46. Incremental Cost of Single to Dual Enthalpy

Base Cost Factor Total Costs			
HVAC System Capacity (Tons)	Dual Enthalpy Control	Dual Enthalpy Control Installation	Measure Total
5	$106	$72	$178
15	$179	$72	$251
25	$252	$72	$324
40	$362	$72	$434
70	$581	$72	$653

3.4.4 Issues/Resolutions

The main issue that arose during analysis of the economizers measure was the baseline. Initially, the analysis was performed only considering one baseline situation (dry-bulb single-enthalpy economizer); however, discussion with Technical Advisors and other subject matter experts resulted in defining a second baseline scenario in which an existing piece of HVAC equipment had no economizer installed. Accordingly, costs for both scenarios were developed and are presented in the report and the accompanying workbook. Once this change was made, the analysis was straightforward and no further issues were encountered.

3.5 *Variable Frequency Drives (VFDs)*

3.5.1 Characterization

Based on conversations with technical advisors, the baseline unit for the VFD measure was chosen to be a unit without a VFD installed. The difference in efficiency between VFDs operating on the same size equipment is insignificant compared to the efficiency gain associated with installing a VFD. As a result, the measure-level unit is defined as equipment with a variable frequency drive installed. Additionally, technical reviewers recommended that the scope of the interviews be limited to drives of 15 HP or less. Table 47 describes VFD characterization.

Table 47. Variable Frequency Drive Characteristics

Baseline Description	No VFD installed
Baseline Efficiency Levels	No defined efficiency level
Measure-Level Description	VFD installed
Measure Efficiency Levels	No defined efficiency levels
Sizes	0 – 600 HP, grouped into three buckets: 0-25 HP, 30-75 HP, 100-600 HP
Distinguishing Features	None other than size
Installation Scenarios	VFD Bypass is optional add-on equipment that is highly recommended by installers. Most installation scenarios involve sensors and other electrical equipment.

3.5.2 Data Collection

National Grid provided contact information for contractors who may have performed VFD installs in the last three years. This resource was exhausted and 16 successful phone interviews were conducted. After the interview round was complete, there was a second effort to collect data, however, this time for units above 15 HP. For this second effort, Navigant added raw data from the Database for Energy-Efficient Resources (DEER) 2008 Study as well as data collected by parsing through National Grid invoices of VFD rebates in the past three years. Many of the invoices were for multiple measure projects and the specific VFD costs were often not shown individually, limiting the usefulness of this data source.

3.5.3 Results

Table 48 shows the cost results for installation of VFDs at different horsepowers.

Table 48. Variable Frequency Drive (VFD) Costs

Size (HP)	Base Cost Factor ($/Unit)		
	Equipment Cost	Labor Cost	Total Installed Cost
5	$1,115	$1,135	$2,250
15	$2,183	$1,135	$3,318
25	$3,250	$1,135	$4,386
50	$5,438	$1,135	$6,573
75	$7,397	$1,135	$8,532
100	$8,848	n/a*	n/a
200	$15,301	n/a*	n/a

*Labor costs were not determined for these larger units.

3.5.4 Issues/Resolutions

The major issue that arose during the analysis of the VFDs measure was the range of units Navigant initially reported. During the characterization phase, technical advisors recommended we limit our scope to units below 15HP. However, when the preliminary analysis results were presented, additional technical advisors responded that we needed to consider larger units in our analysis. This issue was resolved by collecting more data, as there were many units above 15HP in the new data set, extending the range to 600HP. Additional issues arose regarding how the analysis was performed and how the results were presented. For instance, once the new data was incorporated into the data set, the range of sizes was much greater than before, so the units were divided into size buckets (e.g., 0-15 HP, 15-30 HP). The rationale for this division was that performing a single regression on the entire size range would produce unreliable results (or low R^2); individual regressions performed on each size bucket would each have stronger and more reliable results (or higher R^2). However, the division of the data into too many size buckets created continuity problems in the results, and also weakened the strength of the regressions performed. The issue was resolved by using only three size buckets (0-25 HP, 30-75 HP, and 100-600 HP), as this method produced reliable results (high R^2) while maintaining a large enough sample space for each size bucket.

3.6 Residential Ductless Mini-Splits

3.6.1 Characterization

Residential ductless mini-split systems (mini-splits) are an HVAC technology that provides forced air (either heated or cooled) to one or many spaces in a home. Mini-split units consist of an outdoor condenser and an indoor air-handling unit. Rather than using ductwork to force the air to various rooms in a home, smaller and easier to install condensate piping is used. Unlike traditional HVAC technologies, mini-splits are more efficient because they allow users to heat or cool specified areas, rather than the entire ducted system. In cases where they are also used for heating, they run on electricity rather than natural gas.

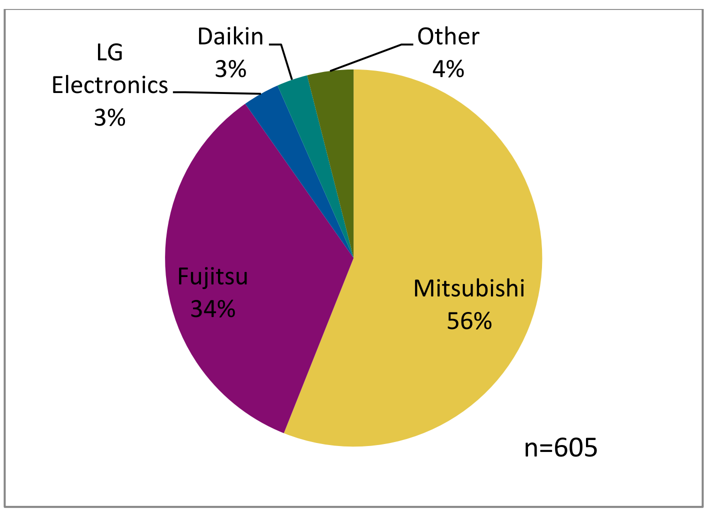
3.6.1.1 Market Characterization

When designing the study, Navigant worked with the TAGs to characterize each technology so that data could be collected in a standardized way that would reflect the most typically installed units. Navigant also analyzed the NSTAR program tracking database to assess prevalence of various manufacturers, unit size, SEER levels, and brands rebated. While the rebate data represents only a portion of the mini-split market, we used it as a proxy to understand trends in the overall mini-split market and also to inform the design of the study.

Mini-split technology has been available for many years and is pervasive outside of the U.S.[25] However, mini-split penetration in the Northeast is relatively recent; for some time, mini-splits with a heating capability did not meet average winter temperatures found in much of the Northeast. Current models are generally rated at low temperatures of 17°F. At least two companies now offer units capable of providing heat at 0°F.

Using the NStar market as a proxy for the NEEP member market, Navigant found two manufacturers that make up the majority of the mini-split market—Mitsubishi, followed by Fujitsu. Figure 4 shows the breakout of manufacturers as a percent of the NSTAR market.

Figure 4. Mini-Split Manufacturers Represented by NSTAR Market



Mini-split units are available in various sizes and SEER levels. The size of the outdoor unit installed is relative to the sizes of the indoor space(s) and the number of indoor units that are installed. Table 49 and Table 50 show the breakout of size and SEER levels rebated by NSTAR. They indicated that 70 percent of all rebates were for ¾ or 1-ton units and the majority of units are SEER 18 and higher, several levels higher than the ENERGY STAR rating.

[25] Interview with Eric Dubin, Manager of National Accounts and Utilities with Mitsubishi Electronics of America, talking about market share in Europe and Asia, October 25, 2012.

Table 49. Representation of NSTAR Rebated Ductless Mini-Splits by SEER

SEER	Quantity	% of total
15	1	0%
16	31	5%
17	18	3%
18	79	13%
19	30	5%
20	91	15%
21	153	25%
22	6	1%
23	46	8%
24	0	0%
25	69	11%
26	81	13%
Total	**605**	**100%**

Table 50. Representation of NSTAR Rebated Ductless Mini-Splits by Size (Tons)

Tons	Quantity	% of Total
3/4 or 1*	424	70%
1.5	110	18%
2	70	12%
2.5	1	0.2%
Total	**605**	**100%**

* 3/4 ton units were not accurately represented in NSTAR database and, therefore, are included with one-ton units.

The findings of this market characterization guided the interview process, and suggested that the study should focus on 1-ton units to make data collection from contractors reasonable. To establish a typical installation scenario for the study, Navigant focused the study on single-zone, rather than multi-zone systems.

3.6.1.2 Baseline Scenario(s)

Navigant initially characterized a full cost scenario, assuming that no air conditioning existed and therefore the full cost of the mini-split system should be determined. However, in the review process, it became clear from comments that a viable scenario also exists for considering the incremental costs of a more efficient mini-split system against a SEER 13 unit. As a result, Navigant presents both full and incremental cost scenarios:

Full Cost. There are several possible baseline scenarios for ductless mini-split systems. Navigant's analysis initially focused on scenarios where there was no prior HVAC unit installed and the customer either cannot or would not consider installing ductwork for a traditional ducted system. As such, the analysis of ductless mini-splits was initially based on the full cost, rather than an incremental cost of a different type of heating or cooling system. Table 51 illustrates some assumptions that one might consider for various scenarios for either a cooling only or cooling and heating system.

Incremental Cost. Reviewers recommended that Navigant provide an incremental cost analysis as well as the full cost analysis, since lower efficiency units are available in the marketplace. The ENERGY STAR standard for mini-splits begins with a minimum qualifying efficiency of 14.5 SEER. That is also the efficiency at which several program administrators begin their incentives. Navigant therefore presents an incremental scenario based upon a baseline of SEER 13.

Table 51. Baseline Scenarios for Residential Ductless Mini-Splits

Specifications	Cooling Only		Cooling and Heating		
Baseline Description	No A/C	Room A/C choice of mini-split	No A/C	Room A/C	Electric baseboard heat
Baseline Efficiency Levels	N/A	Base SEER 13	N/A	≤ SEER 14, ≤ EER 12	100%
Measure-Level Description	ENERGY STAR rated ductless mini-split system A/C		ENERGY STAR rated ductless mini-split system HP heat pump		
Measure Efficiency Levels	14.5-17 SEER, 12-13.5 EER		14-26 SEER, 11.5-13.5 EER, HSPF 8.2-10		
Measure Distinguishing Features	Single- or multiple-zone capacity		Single- or multiple-zone capacity; high heating at 47°F; low heating at 17°F		
Installation Scenarios	AC cooling only; equipment upgrade/addition		HP cooling and heating; equipment upgrade/addition; electric baseboard heat would not be replaced but potentially retired in exchange for use of heat pump heating capability		

Data Collection

Cost research on mini-splits was conducted via contractor interviews and Internet research. A total of 13 contractor interviews were completed with contractors in various parts of Massachusetts. Contractor information was derived from the NSTAR program tracking database and only contractors who had been rebated for ductless mini-split systems were contacted. Those who had been rebated for at least four units were prioritized to ensure greater breadth of experience among respondents. All 12 NYSERDA contractors were called; however, none resulted in completed interviews.

Internet data was used to collect material costs and was taken from a variety of distributor websites. Navigant did not collect Internet data for the cost of labor.

Raw data from both contractor interviews and Internet research were consolidated and normalized where appropriate to account for regional adjustments and outliers.

3.6.2 Results

Navigant presents two sets of results. First, we present a full cost scenario in Table 48, assuming no previous AC and the potential selection of a high SEER qualifying unit. Second, we present an incremental cost table using a SEER 13 baseline mini-split against a minimum ENERGY STAR efficiency of 14.5 SEER and above, in Table 52. Table 53 shows an incremental case against a SEER 13 mini-split.

Table 52. Residential Ductless Mini-splits – Full Cost

Total Installed Cost				
Size (Tons)	Base Cost Factor Full Cost ($/Unit)			
	13 SEER	18 SEER	21 SEER (most represented)	26 SEER (best available)
3/4	$2,733	$3,078	$3,236	$3,460
1	$2,803	$3,138	$3,407	$3,363
1.5	$3,016	$3,374	$3,640	*
2	$3,273	$3,874	*	*

Labor costs were determined to be $1,736 per unit, regardless of size or capacity, for single-room units. Thus, there is no incremental labor cost.

Table 53. Residential Ductless Mini-splits Baseline SEER 13, Incremental Costs for Higher SEERs

Incremental Material Cost			
Size (Tons)	Base Cost Factor ($/Unit)		
	18 SEER	21 SEER (most represented)	26 SEER (best available)
3/4	$345	$503	$727
1	$335	$603	$560
1.5	$358	$624	*
2	$601	*	*
* = Insufficient data available			

3.6.3 Issues/Resolutions

Several comments were received concerning the scope of the preliminary costs, particularly the limitation of the analysis to single-room units, SEER. In response to another comment, fractional SEERs were rounded to ensure that all possible data points were included. Material costs were then averaged by SEER and BTU and values are reported where sufficient data points were available.

Three additional issues were raised through the emerging technologies study sponsored by the EM&V Forum. In part these issues were driven by the needs of some program administrators to provide cost-effective, non-fuel switching alternative measures. Although where fuel switching is permitted, these measures should be highly cost effective replacing oil heat. Some of these issues can be addressed in this study but not all of them; mini-splits are a measure that Navigant believes will continue to evolve in both technology and the marketplace. The issues are as follows:

1. Recommendation to provide an incremental cost table comparing a "low-efficiency" mini-split to higher efficiency units of the same capacities. Navigant consulted ENERGY STAR and a statewide cooling program and determined to use SEER 13 as the baseline. A table is presented above.
2. Recommendation to provide costs for multi-head, multi-room units. While the direct unit materials costs are readily available, hardware (e.g., gas piping, electricals) and labor are highly variable, dependent on the configuration of the home and the additional costs required to reach one or two additional rooms. Installers were quite consistent in not wanting to provide installation costs for multi-room units.
3. Recommendation to provide costs for low-temperature units. Currently available from two manufacturers as single-head units, these mini-splits are capable of providing heat to 0°F without electric resistance heat. These units are expected to be useful for colder northern New England and New York regions. Navigant will review available data, which may be limited for the project's purposes and more an area for further research in another project.

3.7 ENERGY STAR Ventilation Fans

3.7.1 Characterization

Navigant has defined a baseline ventilation fan as a bathroom or utility ventilation fan that is not ENERGY STAR rated. Non-ENERGY STAR units are assumed to be the most economical to purchase. The efficient measure is defined as an ENERGY STAR qualified ventilation fan for the same installation scenario.

While there are many features that ventilation fans may come equipped with, for the purposes of this study, Navigant collected data on standard units, which either come with an integrated light or without. Analysis was done to determine the added cost of an integrated light. Other features, such as the addition of a heating lamp, were not considered for this study and excluded from data collected. Table 54 includes other distinguishing features not considered and provides details on an efficient unit that meets ENERGY STAR requirements.

From the collected data, the following maximum CFM size ranges were used in the analysis of ventilation fan costs: 50–89 CFM, 90–149 CFM, and 150–310 CFM. Units outside these ranges were removed from the formatted data and were not used in the analysis due to insufficient data. There were only a few units below 50 CFM; they were not used in this analysis. Likewise, units above 310 CFM were also rarely encountered and not included in this analysis.

Table 54. Standard Ventilation Fan vs. ENERGY STAR Rated Ventilation Fan Characteristics

Baseline Description	Standard Efficiency Ventilation Fan
Baseline Efficiency Levels	Non-ENERGY STAR rated ventilation fan. Varies by size.
Measure-Level Description	ENERGY STAR Rated Bathroom/Utility Room Ventilation Fan (Residential ventilating fans with heat lamps are excluded.)
Measure Efficiency Levels	Minimum Efficacy Level (CFM/W) Airflow 10 to 89 CFM: 1.4 Airflow 90 to 500 CFM: 2.8 Maximum Allowable Sound Level (Sones) Airflow 10 to 139 CFM: 2 Airflow 140 to 500 CFM: 3 Rated Airflow (0.25 in. w.g.) Airflow 10 to 89 CFM: 60% Airflow 90 to 500 CFM: 70%
Sizes	Varies by room size and function (with or without shower/tub). HVI recommends ventilation of about 1 CFM per square foot (about eight air changes per hour). Up to 500 CFM
Distinguishing Features	1) With or without fluorescent/LED lighting 2) Single/multiple speeds 3) Decorative 4) Ultra quiet 5) Humidity and/or motion sensing, timer control 6) Continuous/intermittent
Installation Scenarios	Ceiling or wall–mounted

3.7.2 Data Collection

Navigant attempted contacting contractors for ventilation fan cost information. Unfortunately, at the time of data collection, contractors were extremely busy and were usually out of the office, and thus unable to participate in the study.

Navigant then turned to online data collection for ventilation fan cost information. Two hundred and twenty-nine cost points were collected across seven online retailers. Online data was taken at the national level and later adjusted for each region after analysis was complete.

A total of 50 calls were made in an attempt to contact contractors for both cost and labor information. Five successful interviews were completed for ventilation fan labor information. Navigant confirmed, with four contractors, there are no incremental labor costs associated with the installation of a ventilation fan. Labor install hours would be the same regardless of the unit's efficiency.

3.7.3 Results

Table 55, Table 56, and Table 57 show costs for three scenarios. Table 55 shows the incremental cost results for residential ventilation fans, using the characteristics and research described above. Table 56 shows replace on burnout costs, including all labor costs. Table 57 shows new construction, including the costs of ducting.

Table 55. Residential ENERGY STAR Ventilation Fan Incremental Costs

Material Incremental Cost Materials			
Base Cost Factor ($/Unit)			
Feature	**CFM Range**		
	50 – 89 CFM	**90 – 149 CFM**	**150 – 310 CFM**
Exhaust only	$80.64	$68.66	$56.19
Fan with light	$123.34	$111.35	$98.89

Incremental costs assume a constant installation cost regardless of size or type.

Table 56. Residential ENERGY STAR Ventilation Fan Replace on Burnout, Full Costs

Feature	CFM Range		
	50 – 89 CFM	**90 – 149 CFM**	**150 – 310 CFM**
Exhaust only	$324.75	$357.39	$386.80
Fan with light	$367.45	$400.09	$429.50

Table 57. Residential ENERGY STAR Ventilation Fan New Construction Full Costs, Including Ducting

Feature	CFM Range		
	50 – 89 CFM	**90 – 149 CFM**	**150 – 310 CFM**
Exhaust only	$584.24	$616.88	$646.29
Fan with light	$626.93	$659.58	$688.99

3.7.4 Issues/Resolutions

While Navigant spoke with contractors to collect labor information, some were not able to provide reasonable average installation times due to the varying installation situations, which call for drastically varying labor hours. Navigant also received comments from workbook reviewers regarding installation labor being dependent on installation location and other added features such as occupancy sensors being installed with the ventilation fan. Contractors also expressed difficulty in determining installation labor required without having a more complete list of installation requirements. One reviewer noted that in new construction, costs should include rigid exhaust ducts.

3.8 *Commercial Refrigeration Compressors (Started but Not Pursued)*

Commercial Refrigeration Compressors—Started but Not Pursued Note: This measure was delayed because the sponsoring program administrator (PA) determined the measure baselines needed to be reset. Subsequently, the PA considered withdrawing the measure as a prescriptive measure and possibly reintroducing it as part of a custom package. The program administrator also noted the measure does not contribute substantially to the portfolio of energy savings. In consequence, work on this measure was first delayed; a further review resulted in a decision not to pursue the measure and to direct resources to another Task 2 measure. The basic characterization, however, was developed for this measure and is described below.

3.8.1 Characterization

This measure relates to the installation of an efficient refrigeration compressor that exceeds the energy efficiency requirements specified in this characterization, as detailed in Table 57 and Table 58, and is generally regarded as a lost opportunity measure. Typical high-efficiency compressor technologies are described below.

Discus Technology involves using effective gas and oil flow management through valving, which provides the best operating efficiency in the range of the compressor load. This eliminates capillary tubes typically used for lubrication that also offers maximum compressor protection as well as environmental integrity. Discus retainers inside the cylinder also improve efficiency and lower sound levels. Reducing discharge pulsation levels by 20 percent over older reed models accomplishes this. The discus action is similar to a piston in a car engine. There is a moving reed action in the top part of the piston, which decreases lost gas from escaping. This leads to the effective gas utilization mentioned above. Because of the close tolerance maintained by this discus retainer to the top of the compressor structure, the fluid loss is minimized and adds to efficiency; however, this same tight tolerance requires completely particle-free fluid to pass through it.

Scroll Technology involves using two identical, concentric scrolls, one inserted within the other. One scroll remains stationary as the other orbits around it. This movement draws gas into the compression chamber and moves it through successively smaller pockets formed by the scroll's rotation, until it reaches maximum pressure at the center of the chamber. At this point, the required discharge pressure has been achieved. There, it is released through a discharge port in the fixed scroll. During each orbit, several pockets are compressed simultaneously, making the operation continuous.

Semi-hermetic compressors raise gas pressure and transport the gas through a piping system for system distribution needs. Electricity energizes the motor, which causes the compressor crankshaft to rotate. The compressor pump contains a piston, which creates a low-pressure rear between the piston top and the cylinder head during the down-stroke. Gas rushes through a suction valve inlet and into the low-pressure area. During the piston up-stroke, the suction valve closes, which forces the exhaust valve to open due to increasing pressure. The gas is compressed and forced through discharge, or high-pressure side of system.

Table 58 provides the measure characterization.

Table 58. Commercial Refrigeration Compressors Characterization

Baseline Description	Within each capacity range for each temperature application, the baseline EER rating is the lower of the hermetic and semi-hermetic compressor EER rating.
Baseline Efficiency Levels	Varies by capacity range and temperature application.
Measure-Level Description	For high- and medium-temperature applications, a 10% EER improvement over baseline EER ratings. For low-temperature application, a 7% improvement over baseline EER rating.
Measure Efficiency Levels	Varies by capacity range and temperature application.
Sizes	Each temperature application has various capacity bins that were sized to roughly correlate to 1HP power increments.
Distinguishing Features	Three different technologies considered: Semi-hermetic, scroll, and discus.

3.9 *Commercial Boiler Controls (Not Pursued)*

3.9.1 Characterization

This measure applies to after-market reset controls that have been installed on existing commercial boilers (300-2,000 kBtu/h). Such controls provide a slight increase in energy efficiency by taking into account outdoor temperature. High-efficiency condensing boilers already incorporate outdoor temperature into their built-in controls, so this measure is limited to existing non-condensing boilers.

Table 59. Efficiency-Level Specifications for Combination Units

Efficiency Level	Description
Baseline	Standard 80% AFUE Boiler
High-efficiency	Standard 80% AFUE Boiler with outdoor reset control installed

3.9.2 Initial Findings/Measure Reconsideration

After a number of initial interview attempts, the team found that this measure is not very common. Contractors reported that customers with aging boilers tend to forgo the retrofit controls option and replace the boiler with a new high-efficiency unit. Even though some savings can be achieved via reset controls, there is a high potential that comfort can be negatively affected, requiring multiple service calls to re-tune the system.

The team reported these initial findings to NEEP in early August, and NEEP decided to poll several program administrators about participation in this measure. NEEP found that participation was very low during the past three years. Given the low levels of participation and limited applicability, Navigant recommended and NEEP decided to terminate research on this measure.

3.10 Energy Management Systems in Commercial Buildings (Not Pursued)

Energy Management Systems control a wide variety of systems within individual buildings, and within larger facilities, may encompass heating, cooling, and/or lighting. In industrial facilities, some or all of certain process needs may be mediated by energy management systems. EMSs are typically constructed of two essential components. First, there is a variety of sensors that report things such as air flow, temperature, light levels, motion, and other conditions that affect a facility's energy use, generally on a real-time basis. Second, there are controllers or systems, which can be as simple as timers that turn systems on and off at designated times, to systems that monitor energy use across a variety of end uses and equipment in a single facility or in multiple facilities. The complexity and cost of controllers (and to a lesser extent sensors, which are generally referred to as "points") vary greatly.

The goal of characterization for the ICS was to construct one or more models of a "typical" EMS that would qualify for prescriptive rebates and research the materials and cost of the models. Navigant posited scenarios based on a commercial building of various sizes and attempted to model which end uses and equipment would be controlled. Navigant requested NEEP's assistance in this effort, working with a NEEP consultant who had many years of program design and implementation experience in the Commercial/Industrial sectors. Though specifying a facility size and end uses was relatively easy, the modeling effort was not able to agree on a typical control configuration that would be amenable to costing on a prescriptive basis. Cost per point could be established; Navigant researched commercial lighting controls in the 2010-2011 ICS but those were direct controllers placed on equipment, not systems. The major problem was specifying the functionality of the controller. After some attempts, the end result was that EMS could not be effectively characterized and costed in a manner that would be sufficiently useful to program administrators. Therefore, the investigation of this measure's costs did not go forward.

4 Data Collection and Analysis

4.1 Introduction

In this section, Navigant describes the methodology used in developing the ICS analysis framework, our approach to data collection, and the analytical methods and assumptions Navigant used to produce costs for the project measures. The approach incorporates the data developed during the 2010 ICS effort, the acquisition of recent cost data during this study, robust analysis, testing, and cross-referencing to other relevant sources, and feedback from primary sources and subject matter experts as Technical Advisor Groups (TAG)s, 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 (QC) 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
» Quality Control, TAG Review and Adjustment
» Multiple Internal QC Reviews
» Conclusions

4.2 Data Collection

The team began by developing data collection instruments specific to each measure that leveraged the instrument templates developed for the 2010 ICS study. Navigant then vetted these 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. Navigant also leveraged the lessons learned and techniques developed during the 2010 effort to ensure that the data collection effort was streamlined, efficient, and captured the most comprehensive and complete information available from installers. For example, Navigant found that several questions in initial instruments were distracting to installers and produce guesses rather than real answers. The team stripped out all nonessential questions and reduced the survey time to a maximum of ten minutes for most measures. 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.

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 the following:

- 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

For some measures, 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. The 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 data sets, several trends including market shares and other key characteristics were calculated. Installation costs, or other cost information found in the tracking databases, were not leveraged for this study.[26]

4.2.1.1 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, such 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
- Provide both materials and labor costs

[26] Navigant did use insulation costs contained in one program administrator database to cross-check data collected through interviews. Navigant also made some use of invoice data from one program administrator in researching costs for VFDs and economizers; in most cases those measures were part of larger projects and the individual measure costs could not be easily isolated.

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

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.
» When available, 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.

4.2.2 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. 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. Finally, we know from projective studies such as DOE's work on appliance standards,[27] that manufacturing costs differ greatly when comparing the current market baseline with efficient alternatives.

[27] 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

4.2.2.1 *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 measures, 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. Navigant found that conducting interviews with contractors during the summer months that installed cooling systems was particularly difficult, as the participating contractors were hard to reach, and at times, unwilling to participate.

In general, the project team found that many 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.

4.2.2.2 *Use of Program Administrator Invoices and Cross-Checks on Costs*

In the 2010-2011 ICS, Navigant encountered the difficulties noted above in obtaining access to program administrator database records for each of the project measures. Because of this, Navigant made efforts to access some invoice records as a compensating measure in 2012. There were two such instances. In the first, one program administrator provided a very large amount of data on CD, encompassing more than 200 records each for chillers, economizers, and VFDs. On examining the invoices, Navigant found that most invoices involved multi-measure projects for which the equipment costs were combined. We found a small number of usable invoices for chillers, about 40 usable invoices for VFDs, and a small number for economizers. In each case the usable data were added to interview and other data collected for the study, increasing the data points for the analysis.

The second case involved using program administrator data to cross-check costs developed from the measure interviews. In this case, Navigant developed costs for Attic Insulation through interviews and was able to cross-check costs quoted by installers against the costs recorded for those same installers in the program administrator's database. This cross-check satisfied some concerns that installers might be reporting inflated costs to Navigant interviewers; the review actually found that costs reported in the database were higher than the costs reported in several interviews. This cross-check shows the value of such work; however, it is hampered by the difficulty of obtaining costs, which are generally held by installation contractors not program administrators, making access that much more difficult.

4.2.2.3 Standard Interview Protocols

To ensure consistency of approach for a number of study measures, Navigant developed a standard template, 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.

4.2.3 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.

4.2.3.1 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[28] 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 R.S. Means data. Navigant determined the total number of interviews that the study

[28] 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 U.S. Navigant used these cost factors to adjust Non-Regional Specific Costs developed for the ICS.

would support and allocated an equal number of interviews to each project measure. 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.

4.2.4 Data Collection for Primary Research

Data collection for primary research for the measures chosen by the Subcommittee consisted primarily of interviews conducted by experienced Navigant staff with equipment installers and distributors, using the Phase One installer/distributer interview protocols reviewed by NEEP and the Technical Advisory Group and modified for specific measures in Phase Two. Navigant determined that 12 contractor and distributor interviews would be completed for each of the Task 1 measures, and 14 interviews would be completed for each of the Task 2 measures. These interview targets were determined by the goal of reaching 90/10 precision and project time and budget resources available, based upon Navigant's experience in Phase One and available budget. In order to assure that interviews were conducted as broadly as possible, Navigant allocated interviews by market region. Table 60 shows the interview allocations and completions by measure and market. Navigant completed 104 interviews. In order to achieve that number, Navigant staff made 1,015 calls.

Table 60. Interview Allocations and Completions for Primary Research

		Condensing On-Demand Water Heaters	Attic Cellulose Insulation	Combination Heat/ Hot Water	Residential Minisplits*	ENERGY STAR Ventilation Fans**	Prescriptive Chillers	Economizers	VFDs
Interview Quota		10	10	10	15	15	16	16	16
Installer Completed Interviews									
Market	Regions	1	0	3	0	0	0	0	0
1	Northern New England (ME, VT, NH)	7	2	0	13	0	9	6	12
2	Central/Southern New England (MA (exc Boston), RI, most CT)	0	0	0	0	0	0	0	4
3	New England City (Boston, Providence)	0	6	0	0	1	0	2	0
4	NY Metro (NYC, Metro, Suburbs, Southeast CT)	0	1	1	0	4	0	1	0
5	NY Upstate (Buffalo, Rochester, etc.)	1	5	6	0	0	5	0	0
6	Mid-Atlantic (MD, DE, DC)	1	0	3	0	0	0	0	0
Distributor Completed Interviews									
1	Northern New England (ME, VT, NH)	0	0	0	0	0	0	0	0
2	Central/Southern New England (MA (exc Boston), RI, most CT)	0	0	0	1	0	0	1	0
3	New England City (Boston, Providence)	0	0	0	0	0	0	0	0

		Condensing On-Demand Water Heaters	Attic Cellulose Insulation	Combination Heat/ Hot Water	Residential Minisplits*	ENERGY STAR Ventilation Fans**	Prescriptive Chillers	Economizers	VFDs
4	NY Metro (NYC, Metro, Suburbs, Southeast CT)	0	0	0	0	0	0	0	0
5	NY Upstate (Buffalo, Rochester, etc.)	0	0	0	0	0	1	0	0
6	Mid-Atlantic (MD, DE, DC)	0	0	0	0	0	1	0	0
Interviews Declined		10	8	31	1	7	16	6	7
Unable to reach contact (multiple calls, messages not returned, bad numbers, etc.)		84	41	183	41	38	141	97	210
Total Successful Calls		**9**	**14**	**10**	**14**	**5**	**16**	**10**	**16**
Total Unsuccessful Call Attempts		94	49	214	42	45	157	103	217
Total Call Attempts		103	63	224	56	50	173	113	233

Navigant completed 104 interviews. In order to achieve that, Navigant staff made 1,015 calls. This is slightly better than the 8% ratio of calls to completed interviews achieved in the 2010-2011 ICS. 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 the normal difficulties in contacting installers; however, there were three other factors at 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 obtain 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. Cooling contractors by a matter of circumstance were again not surveyed until the cooling season had begun, making contact that much more difficult. Because of some uncertainty about the Task 2 final budget, the team concentrated on Task 1 measures during the early months of the project, resulting in calling HVAC contractors at least partly in their busy season. Somewhat surprisingly, the team found that chillers have a busy season as well, which coincided almost exactly with the attempts to collect data.

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 measures within each Task. Because of differing time and budgetary resources being available for the two Tasks, the number of interviews per measure in Task 1 differed from the number of interviews per measure in Task 2. Measure interviews were further allocated by region The condensing On Demand water heaters, originally posed as a Task 2 measure, was transferred to Task 1 because on review of the ICS Phase One data, the team found substantial amounts of data for that measure, reducing the need for additional collection. In addition, the costs were updated for inflation. 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 data sets had comprehensive measure information down to the make and model, and provided complete installer contact information. Some data sets 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.

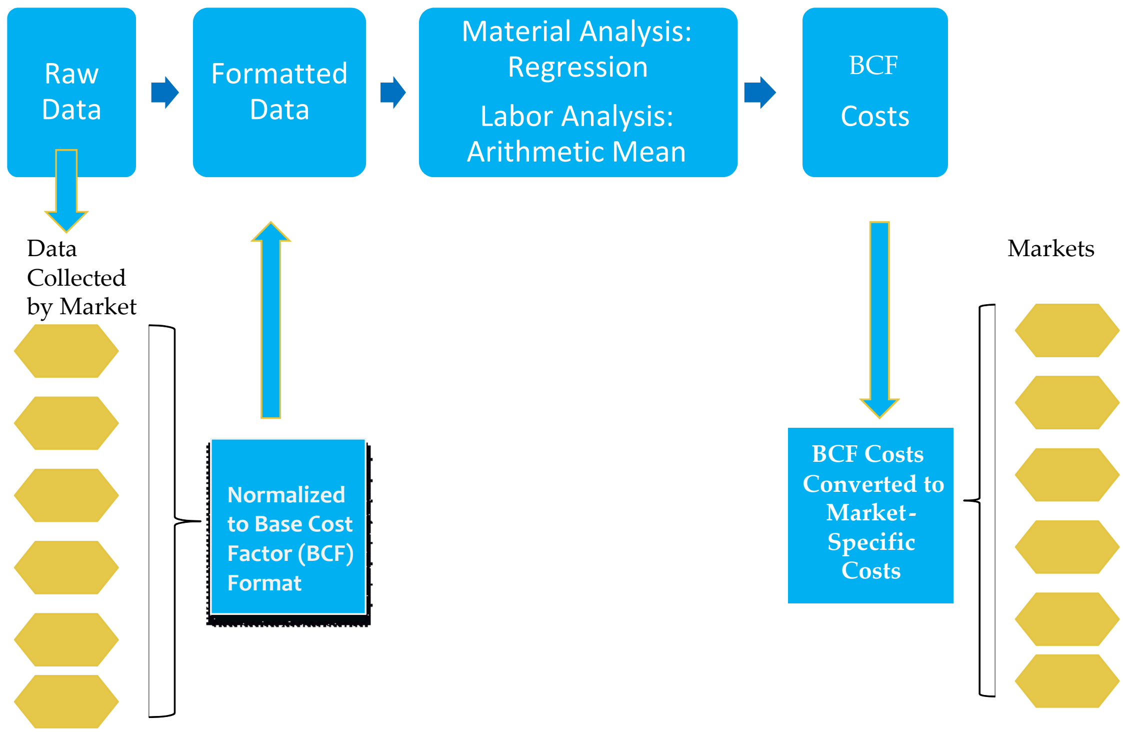
The nature of the rebate structure and types of participants determined the methods used to capture cost data. Typically, telephone interviews were used for equipment contractors and suppliers. Telephone interview questions captured the cost of measures to the consumer. Costs for individual components 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.

4.3 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 Base Cost Factor formats. For example, cost data on insulation collected from Maryland in the Mid-Atlantic were divided by the Mid-Atlantic, Market 6, cost factor 0.77 for materials and 0.89 for labor. The data were then analyzed as a single data set, producing the BCF value for the measure. The

BCF value was then multiplied by the appropriate factor for each market and reported in the report tables. Figure 5 describes the process graphically.

Figure 5. Cost Analysis Process Including Formatting Base Cost Factor 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. Finally, costs from the 2010 ICS effort were incorporated into the Task 1 follow-up measures where appropriate. These data were leveraged in order to increase the overall sample sizes and improve the final results. These previous costs and their elements were also reviewed to ensure consistency between the two years' efforts. As discussed in the next sections, these costs were also adjusted to account for inflation.

The data review and assessment process included the following:

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

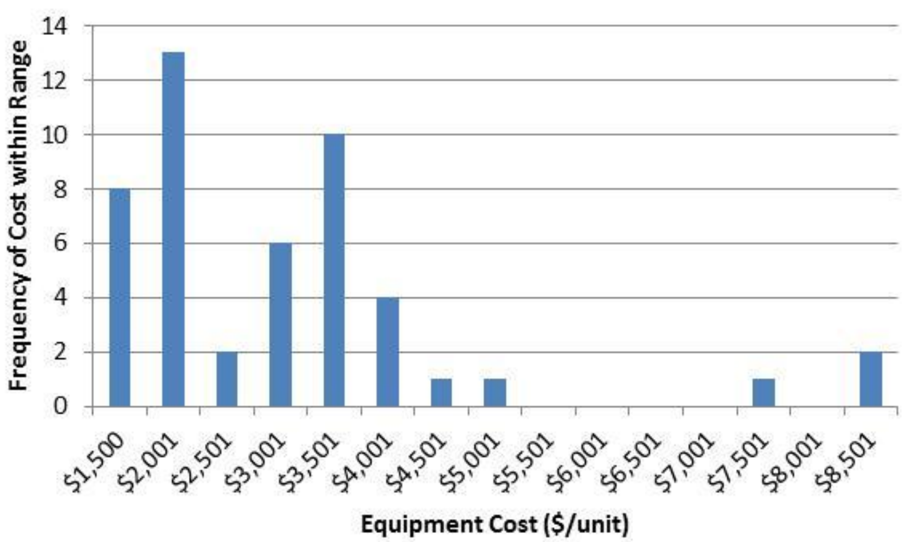
4.3.1 Quality Control

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 data set, 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 discernible 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 data sets 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 6 illustrates these outliers in relation to the remaining sample.

Figure 6. Histogram of Cost Points: Combination Heat and Hot Water Systems



4.3.2 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 BCF 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 61 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. This is done to place data on the same analysis platform no matter where it is collected. Similarly, once the data are analyzed, costs for each market are determined using the R.S. Means adjustment factor. By adjusting costs in this manner, Navigant developed a 'level playing field for analysis purposes and then used the cost factors to specify costs for each market in the study. For example, if the cost provided from a contractor in New York Metro for a piece of equipment was $2,000, then the BCF cost would be:

BCF = Original State Cost ($)/Average Adjustment Factor for Original State or Area
BCF = $2,000/1.29
BCF = $1,593

The same method was used to adjust all labor costs.

Table 61. ICS Markets

Market	Market Code	Regions	Material Adjustment Factor	Labor Adjustment Factor
Northern New England	1	ME, VT, NH	0.98	0.85
Central/Southern New England	2	MA (exc. Boston), RI, most CT	0.99	1.06
New England City	3	Boston, Providence	1.01	1.13
NY Metro	4	NYC, Metro, Suburbs, Southeast CT	1.03	1.29
NY Upstate	5	Buffalo, Rochester, etc.	0.99	1.00
Mid-Atlantic	6	MD, DE, DC	0.77	0.95
Base Cost Factor	-	-	1.00	1.00

Some Internet costs were included in the analysis to augment and 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, and 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, and 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.

Navigant also incorporated costs from the ICS Phase One effort as well as costs from secondary sources. Both of these types of sources originate from older work estimated in previous years. Therefore, the project team adjusted older cost data by accounting for inflation. Costs were adjusted using the U.S. Bureau of Economic Analysis's (BEA's) Gross Domestic Product (GDP) Implicit Price Deflator, which measures the average change over time in the costs of goods sold within the U.S. by examining all aspects of the U.S. economy comprehensively.[29] Several valid cost adjusting factors and methods are available for use. Therefore, as a verification step, the project team also reviewed the Implicit Price Deflator against the Consumer Price Index (CPI) published by the Bureau of Labor Statistics (BLS).[30] For example, for the change from 2010 to 2012, the Deflator and the CPI are 3.21 percent and 3.16 percent, respectively. This is a difference of only 1.7 percent. The project team used the Deflator for this analysis because of the minimal variation in inflation factors seen between various sources and because the Deflator is the most comprehensive factor available. All costs used for the analysis were inflated to values representing the first quarter of 2012.

4.3.3 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 AC, 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.

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[29] GDP Implicit Price Deflator. U.S. Bureau of Economics. U.S. Department of Commerce. Table 1.1.9. http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1.

[30] Consumer Price Index. U.S. Bureau of Labor Statistics. U.S. Department of Labor. ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt.

4.4 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:

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

4.4.1.1 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.

4.4.1.2 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.

4.4.1.3 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.

4.4.1.4 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.

4.5 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

4.5.1 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.

4.5.2 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.

4.5.3 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.

4.6 Estimation of Uncertainty and Implications for the ICS Measure Costs

Prior to finalizing costs for any measure in the ICS, Navigant performed multiple checks to ensure the results were as robust as possible within the study conditions and limitations. These checks included:

- Multiple reviews by technically knowledgeable individuals, including program administrator staff, implementation contractors working in current programs, and NEEP’s own independent consultant.
- Regression analyses for certain measures. The analyses sought to produce a linear equation that fit the raw data well as indicated by a coefficient of determination (R^2) value near 1.0 for each measure. The regression analysis process is iterative; Navigant re-examined its equations and sought additional data to strengthen the relationship between regression equation and raw data, and ultimately the final results.
- Average analyses for certain measures. Certain costs were characterized with averages. This was appropriate for measures that are typically constant and not described by a range of descriptive values (e.g., input capacity). Navigant re-examined its raw data groupings to ensure that equipment used for averages were similar and that outliers were excluded. Groupings were reorganized to reduce standard deviations.
- Comparison of results to other studies, such as a recent National Renewable Energy Laboratory (NREL) study: http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=41

Navigant determined precisions for full and incremental measure costs. Each cost component used to develop the incremental cost was accounted for (e.g., baseline/measure material, labor rates, and baseline/measure labor hours) and the uncertainty analysis was then rolled up to the installation cost (either full or incremental). The detailed steps included the following:

- Computing an average value for each component based on the raw data BCF values
- Computing the precisions for each component at the 90 percent confidence level
- Calculating an average incremental cost (full or incremental) based on the average values for each cost component and the appropriate arithmetic for the given measure
- Calculating the installation cost precision (+/-$) associated with each average incremental cost by summing the precisions for each cost component; the summation procedure differs slightly depending on if components are added/subtracted or multiplied.
    - Adding/subtracting: Absolute precision values ($) are summed (e.g., adding material to labor costs).
    - Multiplying: Percent precision values (%) are summed (e.g., multiplying labor rates by labor hours).
- Percent precision is calculated by dividing the total precision by the average incremental cost previously computed.

Table 62 shows the precisions at the 90 percent confidence level calculated for each measure and a portion of sub-measures where the precision ranges vary. The precision values are valid for the full set of final results presented by Navigant. These values are *approximate uncertainties* as they are percentages based on an average computed from the raw data (adjusted to BCF level) that reflect a range of equipment sizes and efficiencies. The percent uncertainties are applicable to all results, and not any one final result that reflects a specific equipment size and efficiency. These precision estimations are for the *total* costs of labor and materials. In Phase One, Navigant was able to determine precision *separately* for materials and labor but not the combined costs because of the design of data collection and analysis. In Phase Two, we modified our design to enable determining precision on the total costs; thus, these estimations of uncertainty about *total* costs *are not directly comparable* to the *separate* materials and labor precisionestimations made in Phase One.

The precisions at the 90 percent confidence level can be principally explained by three factors:

1. Small sample size. A small final sample size means that outlier costs have a more significant impact on the final results. Small sample sizes result from budgetary limitations and from low response rates in this and the first ICS. Sample quotas were developed from the budgetary resources available based upon the costs/interview determined from the first ICS. Where possible, primary measure data were supplemented with data from secondary sources, such as other cost studies (adjusted for inflation), and from Internet data (adjusted for contractor markup) where available. Secondary data did not always report costs in the same manner as the ICS interviews, adding some further uncertainty.
2. Ideally, cost studies rely on utility programs' tracking of participating installers. This tracking data generally does not directly provide costs at the granularity required for the study but it does provide detailed data on what makes and models and efficiencies of equipment receive incentives, which enhances the research focus. Program Administrator data also provides contact information for participating installers, directing research toward a population that's more motivated to participate. Unfortunately, obtaining these data, which are most commonly

held by implementation contractors, has been difficult. Overall, the installer response rate in Phase Two was 10 percent, an improvement over the first ICS. This low response rate meant there were fewer data points for some measures and undoubtedly affected precision and the estimated uncertainties should be viewed with these and other related circumstances in mind.

3. Large numbers of cost components used to develop incremental costs cause errors to propagate; that is, an increase in moving parts increases the observed uncertainty when the calculation is rolled to the full cost level. Thus, we can expect to find larger variances at the total cost level compared to the variances of the component parts .
4. Large variability (i.e., standard deviation) among the raw data. Some of the measures have multiple components and greater uncertainty at the component level that impact the results for the measure as a whole. High variability is common among incremental cost studies as several factors influence cost, including, but not limited to, competition, contractor experience, and installation methods (i.e., labor hours), and the product offerings.

Table 62. Analysis of Materials and Labor Variances at the 90 Percent Confidence Interval

Task Group	Sector	Measure	Sub-Measure	Full Installation
1	Residential	Condensing On Demand Water Heaters	**All (incremental)**	**24.63%**
1	Residential	Attic Cellulose Insulation	**All (average)**	**24.74%**
			R-38	23.25%
			R-49	21.37%
			R-60	29.61%
1	Residential	Combination Heat/Hot Water	**All (incremental)**	**44.12%**
2	Residential	Residential Mini-Splits	**All (average)**	**8.32%**
			13 SEER 0.75 ton	7.20%
			18 SEER 0.75 ton	11.58%
			21 SEER 0.75 ton	7.06%
			26 SEER 0.75 ton	11.17%
			13 SEER 1 ton	7.25%
			18 SEER 1 ton	10.56%
			21 SEER 1 ton	6.99%
			26 SEER 1 ton	6.63%
			13 SEER 1.5 ton	6.91%
			18 SEER 1.5 ton	8.96%
			21 SEER 1.5 ton	6.43%
			26 SEER 1.5 ton	N/A
			13 SEER 2 ton	7.64%
			18 SEER 2 ton	9.78%

Task Group	Sector	Measure	Sub-Measure	Full Installation
			21 SEER 2 ton	N/A
			26 SEER 2 ton	N/A
2	Residential	ENERGY STAR Ventilation Fans	**All retrofits (average)**	**47.74%**
			Exhaust only retrofit (10 to 89 CFM)	30.51%
			Exhaust only retrofit (90 to 149 CFM)	47.98%
			Exhaust only retrofit (150 to 310 CFM)	56.83%
			Fan with Light retrofit (10 to 89 CFM)	40.60%
			Fan with Light retrofit (90 to 149 CFM)	52.46%
			Fan with Light retrofit (150 to 310 CFM)	58.05%
			All full cost installations (average)	**35.90%**
			Exhaust only full cost replacement (10 to 89 CFM)	23.17%
			Exhaust only full cost replacement (90 to 149 CFM)	27.78%
			Exhaust only full cost replacement (150 to 310 CFM)	28.85%
			Fan with Light full cost replacement (10 to 89 CFM)	28.44%
			Fan with Light full cost replacement (90 to 149 CFM)	32.58%
			Fan with Light full cost replacement (150 to 310 CFM)	33.70%
			Exhaust only full cost new installation (10 to 89 CFM)	39.95%
			Exhaust only full cost new installation (90 to 149 CFM)	42.61%
			Exhaust only full cost new installation (150 to 310 CFM)	43.51%
			Fan with Light full cost new installation (10 to 89 CFM)	41.48%
			Fan with Light full cost new installation (90 to 149 CFM)	43.97%
			Fan with Light full cost new installation (150 to 310 CFM)	44.82%
2	Commercial	Prescriptive Chillers	**All (average)**	**20.13%**
			Air-Cooled Chiller, 50 to 150 tons, Incremental Cost	22.72%
			Air-Cooled Chiller, 200 to 400 tons, Incremental Cost	29.07%
			Water-Cooled Scroll/Screw Chiller, 50 to 150 tons, Galvanized Tower, Incremental Cost	15.82%
			Water-Cooled Scroll/Screw Chiller, 200 to 400 tons, Galvanized Tower, Incremental Cost	20.55%
			Water-Cooled Scroll/Screw Chiller, 50 to 150 tons, Stainless-Steel Tower, Incremental Cost	16.08%
			Water-Cooled Scroll/Screw Chiller, 200 to 400 tons, Stainless-Steel Tower, Incremental Cost	20.43%
			Water-Cooled Centrifugal Chiller, 100 to 250 tons, Galvanized Tower, Incremental Cost	18.20%
			Water-Cooled Centrifugal Chiller, 250+ tons, Galvanized Tower, Incremental Cost	20.11%
			Water-Cooled Centrifugal Chiller, 100 to 250 tons, Stainless-Steel Tower, Incremental Cost	18.25%

Task Group	Sector	Measure	Sub-Measure	Full Installation
			Water-Cooled Centrifugal Chiller, 250+ tons, Stainless-Steel Tower, Incremental Cost	20.03%
2	Commercial	Economizers	**All (average)**	**14.70%**
			Scenario A: Existing equipment without economizer has dual enthalpy economizer installed.	12.03%
			Scenario B: Existing equipment with single economizer has dual enthalpy economizer installed.	17.37%
2	Commercial	VFDs	**All (average)**	**21.86%**
			0 to 25 HP	14.45%
			30 to 75 HP	23.02%
			100 to 600 HP	28.12%

Finally, although some of these variances appear wide, they are in fact in line with variances found in comparable studies such as the California DEER studies.

4.7 *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 EM&V Forum ICS project manager and the TAG members assigned to each measure for review. TAG members were charged with conducting a review of 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 and assumptions, on any given measure.

4.8 *Methodology 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 Lessons Learned

This is the second year Navigant has conducted cost research for the EM&V Research Subcommittee. During this time the research team has examined more than 25 energy efficiency measures across the residential and commercial/industrial sectors. This sort of research is highly labor-intensive. At its heart the work requires identifying and defining measures, and interviewing and analyzing the responses of equipment installers across a wide range of measures and also a range of markets. Each stage of the project process poses a number of barriers. Navigant believes good progress has been made in identifying the barriers and working toward the solutions, although it's clear that there is no smooth pathway for doing this work. Below we describe aspects of the study that have caused problems and our recommendations for improvements.

5.1 *Measure Selection Criteria and Process*

The EM&V Research Subcommittee has had the responsibility for selecting the individual measures to be studied, with assistance from NEEP. A few selected measures have turned out to be impractical to research, some for technical reasons, some for programmatic reasons, some because the market has evolved, as in the case of commercial refrigeration controls. Navigant suggests that for any further research, the committee adopt a scoring system that considers several important factors, including one or more of the following, not necessarily in order of importance:

- Extent to which measure is offered by multiple participating project sponsors
- Current or expected contributions to efficiency savings portfolios
- Concentration on "widgets", discrete appliances or equipment, or whose boundaries are readily identifiable if connected to larger systems
- Recently emerged maturing technologies (e.g., combination heat and water studied in the ICS Phase One and Phase Two)
- Climate-sensitive measures applicable to a specific region
- Ready availability/accessibility of measure data in program administrator databases (identify who has best data in advance of selection)
- Technical review by Program Administrator technical advisors as part of selection process

5.2 *Early Identification of Data Resources*

The basic methodology of the ICS studies has been costing of measures that are offered in energy efficiency programs, not a canvass of the entire market. For this reason, these studies have relied on the availability of program administrator data which describe the make/model of rebated equipment, and equally important name and contact information for the measure installers. This approach allows researchers to develop characterizations that closely conform to the program-incented equipment. In the Phase One and Phase Two studies, Navigant canvassed participating program administrators once the study was in progress, which sometimes increased delays. Data at the level of detail needed are often held by implementation contractors and not program administrators, making the process of gaining access more time consuming. Early identification of data sources, in the measure selection process, would certainly help this situation. Navigant did look at some invoices for three commercial measures in Phase Two, thanks to the cooperation of National Grid. These invoices provided significant useful information for one measure and a minimal amount for the other two. Although the project measures were included in most of these invoices, costs were often not separated, nor were labor costs identified. Our conclusion is that the effort vs. reward of collecting and examining the invoices does not point to this as a significant data source for future studies.

5.3 Increased Coordination with Technical Advisors and Program Implementers/Designers

Navigant had more success with soliciting and receiving comments on measure characterization and on preliminary costs in Phase Two, with some limitations. Each participating program administrator designated TAGs for each of the project measures. In addition, several program administrators and Navigant were successful in getting measure reviews from implementation contractors; program administrators also had some measures reviewed by their own consultants.

Response to proposed measure characterizations was most helpful on technical issues. However, we sometimes learned, later in the study, that the technical issues discussed did not always match up well with current or potential programs offered by program. Given the number of participating program administrators in the study, it isn't surprising that the baselines and efficient measure characterizations did not match every program; however, in some cases, getting a program-oriented review as well as a technical one could have avoided some time-consuming adjustments after data were collected and analyzed. Navigant recommends a tighter connection between technical and program reviews in any future cost work. We recognize that the time demands on program administrators often work against such tight coordination; however, the project as a whole is intended to aid the program administrators' planning and evaluation activities and we believe further effort should be invested at the characterization stage as well as cost review to get program-oriented feedback.

Finally, Navigant believes it is extremely important in a project of this complexity for NEEP as administrator of the project to have a dedicated Technical Advisor. The Technical Advisor should have a broad background in the specific measures being researched and/or related expertise in program design. Being able to call on this sort of expertise was extremely valuable for the Task 2 measures, particularly C&I measures. The need is not only for the technical skill but for the context of how program administrator energy efficiency programs are actually planned, implemented, and evaluated. Should the EM&V Forum decide to sponsor further rounds of cost research, we strongly recommend the inclusion of such an advisor as part of the team.

6 Recommendations for Future Cost Work

THE ICS Phase Two expanded the scope of cost research, focusing more on commercial measures in this round of research. In thinking about future cost research, Navigant recommends that such work only focus on four areas:

1. Measures that are currently providing substantial contributions to energy efficiency portfolios
2. Measures in the current study that are estimated to experience frequent cost changes because of developing markets and/or technology changes. Combination Heat and Water Units and Residential Mini-splits fall into this category.
3. Emerging technologies that are fully commercialized (and may now or in the very near future be offered in energy efficiency programs) but also still undergoing technical and market development and have the potential to make substantial contributions to savings portfolios
4. Further exploration of the premium pricing issue. In this particular case, Navigant recommends more consumer-focused research to gain a better understanding of what consumers value in the purchase decisions about energy-using equipment on the one hand. On the other hand, future primary research on the embedded costs of non-energy-saving premium features can also turn to a deep analysis of the sort provided by tear-down analyses that have been done for regulatory purposes. The tear-down work that has been done did not consider this issue and could only indicate where non-energy costs might be found and provide only very rough estimations of their cost contribution. A dedicated tear-down focused on premium features across multiple measures might shed significant light on the subject.

Additionally, Navigant suggests continuing work on two measures considered in this study. Residential Mini-Splits stand out as measures that have a growing role in residential programs and possibly in small commercial programs as well. Multi-head units are becoming more common, and with more installation experience, we would expect that establishing a range of labor costs will become more feasible. Technology changes figure into this measure as well. Low-temperature units are now available from two major manufacturers and we would expect that field to widen. Low-temperature units could play a substantial role in colder rural areas of the Northeast where fuel switching (primarily from oil heat) is permitted.

Navigant also believes that work on commercial refrigeration compressors should be considered. Though not currently a large savings contributor, this measure might have the potential for increased savings share going forward. Navigant suggests that Efficiency Vermont keep the Subcommittee current on how it approaches this measure moving forward.

Navigant invites readers of this report to recommend measures they think might be valuable for any future measure cost research as well. Getting recommendations early and screening following the selection criteria recommended above, might kick-start any future efforts in this area.

Appendix A. Cost Tables for Measures by Market

This appendix contains all measure tables by market, as shown below. For example, to determine the costs for measures in the NY Metro market, click on the hyperlink (A1-A6) in the Appendix Code column below.

Market	Appendix Code	Regions	Material Adjustment Factor	Labor Adjustment Factor
Northern New England	A1	ME, VT, NH	0.98	0.69
Central/Southern New England	A2	MA (exc. Boston), RI, most CT	0.99	1.13
New England City	A3	Boston, Providence	1.01	1.24
NY Metro	A4	NYC, Metro, Suburbs, Southeast CT,	1.03	1.55
NY Upstate	A5	Buffalo, Rochester, etc.	0.99	1.00
Mid-Atlantic	A6	MD, DE, DC	0.77	0.89

The measures for each market are shown in the following order:

Measure	Sector	Fuel	Application	Cost Type	Costs Provided
Task 1: Additional Work on Phase One Measures					
Combination Heat Hot Water	Res	Gas	ROB	Inc	X
Insulation, Attic, Cellulose	Res	Gas	RET	Inc	X
Condensing On Demand Water Heaters	Res	Gas	ROB	Inc	X
Task 2: New Measures					
Chillers, Prescriptive	C&I	Electric	ROB	Inc	X
Dual Enthalpy Economizers	C&I	Electric	RET/NC	Inc, Full	X
Variable Frequency Drives	C&I	Electric	RET	Inc	X
Ductless Mini-Splits	Res	Electric	RET/NC	Inc, Full	X
ENERGY STAR Ventilation Fans	Res	Electric	ROB/NC	Inc, Full	X
KEY: RET = Retrofit, ROB = Replace on Burnout, NC = New Construction, NP = Not Pursued, Inc = Incremental					

A.1 Market 1. Northern New England

Table A1. Combination Heat and Hot Water Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 1 Northern New England Incremental Cost ($/Unit) (Baseline = Standard Hot Water Boiler, 80 AFUE)			
	90 CAE	91 CAE	93 CAE	95 CAE
110	$1,392	$1,666	$2,213	$2,761
120	$1,446	$1,720	$2,268	$2,816
126	$1,479	$1,753	$2,301	$2,849
150	$1,611	$1,885	$2,433	$2,980
199	$1,879	$2,153	$2,701	$3,249

Table A2. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 1 Northern New England Incremental Cost ($/Unit) for Standard Installation			
	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,592	$2,187	$2,236	$2,286
180	$1,502	$2,097	$2,147	$2,196
180	$1,431	$2,026	$2,075	$2,125
199	$1,530	$2,124	$2,174	$2,224
199	$1,395	$1,990	$2,040	$2,089

Table A3. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 1 Northern New England Incremental Cost ($/Unit) for Additional Labor to Relocate Measure			
	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,858	$2,453	$2,503	$2,552
180	$1,769	$2,363	$2,413	$2,463
180	$1,697	$2,292	$2,341	$2,391
199	$1,796	$2,391	$2,440	$2,490
199	$1,661	$2,256	$2,306	$2,355

Table A4. Insulation Incremental Costs

2012 (Combined) Results - Incremental			
	Base Cost Factors by Individual Market ($/SF)		
	38	49	60
Market 1 Northern New England	$1.65	$1.74	$1.83

Table A5. Air-Cooled Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	Northern New England Incremental Cost ($/Ton) (Categorized by Efficiency (EER)) Baseline EER = 9.60				
	9.6	9.9	10.2	10.52	10.7
50	$0	$224	$448	$687	$821
100	$0	$112	$224	$343	$411
150	$0	$75	$149	$229	$274
200	$0	$46	$91	$140	$167
400	$0	$23	$46	$70	$84

Table A6. Water-Cooled Screw/Scroll Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	Northern New England Incremental Cost Estimates (Categorized by Efficiency (kW/Ton) Baseline Efficiency: 0.78 kW/Ton				
	0.78	0.72	0.68	0.64	0.6
50	$0	$74	$124	n/a	n/a
100	$0	$37	$62	n/a	n/a
150	$0	$25	$41	n/a	n/a
200	n/a	$0	$60	$120	$180
400	n/a	$0	$30	$60	$90

Table A7. Water-Cooled Centrifugal Chiller Incremental Costs

2012 (Combined) Results - Incremental				
Capacity (Tons)	Northern New England Incremental Cost Estimates (Categorized by Efficiency (kW / Ton)) Baseline Efficiency: 0.64 kW / Ton			
	0.64	0.6	0.58	0.54
100	$0	$72	$108	$180
150	$0	$48	$72	$120
200	$0	$36	$54	$90
300	$0	$60	$90	$149
600	$0	$30	$45	$75

Table A8. Economizer Incremental Costs- Scenario A

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	Northern New England Incremental Costs ($/Ton)		
	Single Enthalpy Economizer	Dual Enthalpy Economizer Controls	Measure Total
5	$757	$154	$911
15	$1,242	$225	$1,467
25	$1,726	$297	$2,022
40	$2,452	$404	$2,856
70	$3,904	$619	$4,523
Note: Costs are adjusted to account for material and labor costs.			

Table A9. Economizer Incremental Costs- Scenario B

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	Northern New England Incremental Costs ($/Ton)		
	Dual Enthalpy Control	Dual Enthalpy Control Installation	Measure Total
5	$104	$50	$154
15	$176	$50	$225
25	$247	$50	$297
40	$355	$50	$404
70	$569	$50	$619
Note: Costs are adjusted to account for material and labor costs.			

Table A10. VFD Incremental Costs

2012 (Combined) Results – Full Cost			
Size (HP)	Northern New England Incremental Costs ($/Unit)		
	Equipment Cost	Labor Cost	Total Installed Cost
5	$1,092	$780	$1,872
15	$2,137	$780	$2,917
25	$3,182	$780	$3,963
50	$5,324	$780	$6,104
75	$7,242	$780	$8,022
100	$8,662	n/a	n/a
200	$14,980	n/a	n/a

TableA11. Residential Ductless Minisplit Full Costs

2012 (Combined) Results –Full Cost				
Size (Tons)	Northern New England Full Cost ($/Unit)			
	13 SEER	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$2,162	$2,499	$2,654	$2,873
1	$2,231	$2,558	$2,821	$2,778
1.5	$2,439	$2,789	$3,049	*
2	$2,690	$3,279	*	*

Note: Full costs include a factor labor cost of $1,212/unit for all SEERS in the Northern New England market.

Table A12. Residential Ductless Minisplit Incremental Costs Compared to SEER 13 Minisplit

Incremental Material Cost			
Size (Tons)	Market 1 Northern New England Incremental Cost ($/Unit)		
	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$338	$493	$712
1	$328	$591	$548
1.5	$351	$611	*
2	$588	*	*

* = Insufficient data available

Table A13. ENERGY STAR Ventilation Fan Material Incremental Costs

2012 (Combined) Results - Incremental			
Feature	Northern New England Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$79	$67	$55
Fan with Light	$121	$109	$97

Table A14. ENERGY STAR Ventilation Fan Full Installation Cost for Replacement Vent Fan

2012 (Combined) Results - Incremental			
Feature	Northern New England Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$267	$299	$328
Fan with Light	$309	$341	$370

Table A15. ENERGY STAR Ventilation Fan Full Installation Cost for New Vent Fan

2012 (Combined) Results - Incremental			
Feature	Northern New England Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$446	$478	$507
Fan with Light	$488	$520	$549

A.2 *Market 2: Central/Southern New England Incremental Costs*

Table A16. Combination Heat and Hot Water Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 2 Central/Southern New England Average Incremental Cost ($/Unit) (Baseline = Standard Hot Water Boiler, 80 AFUE)			
	90 CAE	91 CAE	93 CAE	95 CAE
110	$1,931	$2,207	$2,761	$3,314
120	$1,986	$2,263	$2,816	$3,369
126	$2,019	$2,296	$2,849	$3,402
150	$2,152	$2,429	$2,982	$3,535
199	$2,423	$2,700	$3,253	$3,806

Table A17. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
	Market 2 Central/Southern New England Incremental Cost ($/Unit) for Standard Installation			
Size (MBH)	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,758	$2,358	$2,408	$2,459
180	$1,667	$2,268	$2,318	$2,368
180	$1,595	$2,196	$2,246	$2,296
199	$1,695	$2,295	$2,346	$2,396
199	$1,559	$2,160	$2,210	$2,260

Table A18. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
	Market 2 Central/Southern New England Incremental Cost ($/Unit) for Additional Labor to Relocate Measure			
Size (MBH)	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$2,196	$2,796	$2,846	$2,897
180	$2,105	$2,706	$2,756	$2,806
180	$2,033	$2,634	$2,684	$2,734
199	$2,133	$2,733	$2,783	$2,834
199	$1,997	$2,598	$2,648	$2,698

Table A19. Insulation Incremental Costs

2012 (Combined) Results - Incremental			
	Base Cost Factors by Individual Market ($/SF)		
	38	49	60
Market 2 Central/Southern New England	$2.01	$2.09	$2.18

Table A20. Air-Cooled Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	Central/Southern New England Incremental Cost ($/Ton) (Categorized by Efficiency (EER)) Baseline EER = 9.60				
	9.6	9.9	10.2	10.52	10.7
50	$0	$226	$453	$694	$830
100	$0	$113	$226	$347	$415
150	$0	$75	$151	$231	$277
200	$0	$46	$92	$141	$169
400	$0	$23	$46	$71	$85

Table A21. Water-Cooled Screw/Scroll Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	Central/Southern New England Incremental Cost Estimates (Categorized by Efficiency (kW/Ton) Baseline Efficiency: 0.78 kW/Ton				
	0.78	0.72	0.68	0.64	0.6
50	$0	$75	$125	n/a	n/a
100	$0	$38	$63	n/a	n/a
150	$0	$25	$42	n/a	n/a
200	n/a	$0	$61	$121	$182
400	n/a	$0	$30	$61	$91

Table A22. Water-Cooled Centrifugal Chiller Incremental Costs

2012 (Combined) Results - Incremental				
Capacity (Tons)	Central/Southern New England Incremental Cost Estimates (Categorized by Efficiency (kW / Ton)) Baseline Efficiency: 0.64 kW / Ton			
	0.64	0.6	0.58	0.54
100	$0	$73	$109	$182
150	$0	$48	$73	$121
200	$0	$36	$54	$91
300	$0	$60	$90	$151
600	$0	$30	$45	$75

Table A23. Economizer Incremental Costs- Scenario A

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	Central/Southern New England Incremental Costs		
	Single Enthalpy Economizer	Dual Enthalpy Economizer Controls	Measure Total
5	$765	$186	$952
15	$1,254	$259	$1,513
25	$1,743	$331	$2,074
40	$2,477	$439	$2,916
70	$3,944	$656	$4,600
Note: Costs are adjusted to account for material and labor costs.			

TableA24. Economizer Incremental Costs- Scenario B

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	Central/Southern New England Incremental Costs ($/Ton)		
	Dual Enthalpy Control	Dual Enthalpy Control Installation	Measure Total
5	$105	$81	$186
15	$177	$81	$259
25	$250	$81	$331
40	$358	$81	$439
70	$575	$81	$656
Note: Costs are adjusted to account for material and labor costs.			

Table A25. VFD Incremental Costs

2012 (Combined) Results - Incremental			
Size (HP)	Central/Southern New England Incremental Costs ($/Unit)		
	Equipment Cost	Labor Cost	Total Installed Cost
5	$1,102	$1,284	$2,386
15	$2,158	$1,284	$3,442
25	$3,213	$1,284	$4,498
50	$5,376	$1,284	$6,660
75	$7,313	$1,284	$8,597
100	$8,747	n/a	n/a
200	$15,127	n/a	n/a

Table A26. Residential Ductless Minisplit Full Costs

2012 (Combined) Results - Incremental				
Size (Tons)	Central/Southern New England Full Cost ($/Unit)			
	13 SEER	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$2,953	$3,294	$3,451	$3,672
1	$3,023	$3,354	$3,620	$3,576
1.5	$3,233	$3,587	$3,850	*
2	$3,487	$4,082	*	*

Note: Full costs include a factor labor cost of $1,995/unit for all SEERS in the Central/Southern New England market.

Table A27. Residential Ductless Minisplit Incremental Cost Compared to SEER 13

Size (Tons)	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$341	$498	$719
1	$331	$597	$553
1.5	$354	$617	*
2	$594	*	*

Table A28. ENERGY STAR Ventilation Fan Material Incremental Costs

2012 (Combined) Results - Incremental			
Feature	Central/Southern New England Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$80	$68	$56
Fan with Light	$122	$110	$98

Table A29. ENERGY STAR Ventilation Fan Full Installation Cost for Replacement Vent Fan

2012 (Combined) Results – Incremental			
Feature	Central/Southern New England Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$346	$379	$408
Fan with Light	$389	$421	$450

Table A30. ENERGY STAR Ventilation Fan Residential Full Installation Cost for New Vent Fan

2012 (Combined) Results - Incremental			
Feature	Central/Southern New England Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$640	$672	$701
Fan with Light	$682	$715	$744

A.3 *Market 3: New England City Incremental Costs*

Table A31. Combination Heat and Hot Water Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 3 New England City Incremental Cost ($/Unit) (Baseline = Standard Hot Water Boiler, 80 AFUE)			
	90 CAE	91 CAE	93 CAE	95 CAE
110	$2,075	$2,358	$2,924	$3,490
120	$2,131	$2,414	$2,981	$3,547
126	$2,165	$2,448	$3,015	$3,581
150	$2,301	$2,584	$3,151	$3,717
199	$2,579	$2,862	$3,428	$3,994

Table A32. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 3 New England City Incremental Cost ($/Unit) for Standard Installation			
	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,827	$2,442	$2,493	$2,545
180	$1,735	$2,350	$2,401	$2,452
180	$1,661	$2,276	$2,327	$2,378
199	$1,763	$2,378	$2,429	$2,480
199	$1,624	$2,239	$2,290	$2,341

Table A33. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
	Market 3 New England City Incremental Cost ($/Unit) for Additional Labor to Relocate Measure			
Size (MBH)	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$2,307	$2,922	$2,973	$3,025
180	$2,215	$2,830	$2,881	$2,932
180	$2,141	$2,755	$2,807	$2,858
199	$2,243	$2,858	$2,909	$2,960
199	$2,104	$2,719	$2,770	$2,821

Table A34. Insulation Incremental Costs

2012 (Combined) Results - Incremental			
	Base Cost Factors by Individual Market ($/SF)		
	38	49	60
Market 3 New England City	$2.12	$2.21	$2.30

TableA35. Air-Cooled Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	New England City Incremental Cost ($/Ton) (Categorized by Efficiency (EER)) Baseline EER = 9.60				
	9.6	9.9	10.2	10.52	10.7
50	$0	$231	$462	$708	$846
100	$0	$115	$231	$354	$423
150	$0	$77	$154	$236	$282
200	$0	$47	$94	$144	$173
400	$0	$24	$47	$72	$86

Table A36. Water-Cooled Screw/Scroll Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	New England City Incremental Cost Estimates (Categorized by Efficiency (kW/Ton) Baseline Efficiency: 0.78 kW/Ton				
	0.78	0.72	0.68	0.64	0.6
50	$0	$77	$128	n/a	n/a
100	$0	$38	$64	n/a	n/a
150	$0	$26	$43	n/a	n/a
200	n/a	$0	$62	$123	$185
400	n/a	$0	$31	$62	$93

TableA37. Water-Cooled Centrifugal Chiller Incremental Costs

2012 (Combined) Results - Incremental				
Capacity (Tons)	New England City Incremental Cost Estimates (Categorized by Efficiency (kW / Ton)) Baseline Efficiency: 0.64 kW / Ton			
	0.64	0.6	0.58	0.54
100	$0	$74	$111	$185
150	$0	$49	$74	$123
200	$0	$37	$56	$93
300	$0	$62	$92	$154
600	$0	$31	$46	$77

Table A38. Economizer Incremental Costs- Scenario A

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	New England City Incremental Costs		
	Single Enthalpy Economizer	Dual Enthalpy Economizer Controls	Measure Total
5	$781	$196	$977
15	$1,280	$270	$1,550
25	$1,778	$344	$2,122
40	$2,527	$454	$2,981
70	$4,024	$676	$4,699
Note: Costs are adjusted to account for material and labor Costs.			

Table A39. Economizer Incremental Costs- Scenario B

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	New England City Incremental Costs ($/Ton)		
	Dual Enthalpy Control	Dual Enthalpy Control Installation	Measure Total
5	$107	$89	$196
15	$181	$89	$270
25	$255	$89	$344
40	$365	$89	$454
70	$587	$89	$676

Note: Costs are adjusted to account for material and labor costs.

Table A40. VFD Incremental Costs

2012 (Combined) Results - Incremental			
Size (HP)	New England City Incremental Costs ($/Unit)		
	Equipment Cost	Labor Cost	Total Installed Cost
5	$1,128	$1,407	$2,536
15	$2,209	$1,407	$3,616
25	$3,289	$1,407	$4,697
50	$5,503	$1,407	$6,910
75	$7,486	$1,407	$8,893
100	$8,954	n/a	n/a
200	$15,485	n/a	n/a

Table A41. Residential Ductless Minisplit Full Costs

2012 (Combined) Results - Incremental				
New England City Full Cost ($/Unit)				
Size (Tons)	13 SEER	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$3,167	$3,516	$3,676	$3,903
1	$3,238	$3,577	$3,849	$3,805
1.5	$3,453	$3,816	$4,085	*
2	$3,714	$4,322	*	*

Note: Full costs include a factor labor cost of $2,186/unit for all SEERS in the New England City market.

Table A42. Residential Ductless Minisplit Incremental Costs

Size (Tons)	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$509	$736	$349
1	$611	$566	$339
1.5	$631	*	$363
2	*	*	$608

Table A43. ENERGY STAR Ventilation Fan Material Incremental Costs

2012 (Combined) Results - Incremental			
Feature	New England City Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$81	$69	$57
Fan with Light	$125	$112	$100

Table A44. ENERGY STAR Ventilation Fan Full Installation Cost for Replacement Vent Fan

2012 (Combined) Results - Incremental			
Feature	New England City Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$369	$402	$432
Fan with Light	$412	$445	$474

Table A45. ENERGY STAR Ventilation Fan Full Installation Cost for New Vent Fan

2012 (Combined) Results - Incremental			
Feature	New England City Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$691	$724	$753
Fan with Light	$733	$766	$796

A.4 Market 4: NY Metro Incremental Costs

Table A46. Combination Heat and Hot Water Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 4 NY Metro Incremental Cost ($/Unit) (Baseline = Standard Hot Water Boiler, 80 AFUE)			
	90 CAE	91 CAE	93 CAE	95 CAE
110	$2,462	$2,751	$3,329	$3,907
120	$2,520	$2,809	$3,387	$3,965
126	$2,555	$2,844	$3,422	$4,000
150	$2,694	$2,983	$3,560	$4,138
199	$2,977	$3,266	$3,844	$4,422

Table A47. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 4 NY Metro Incremental Cost ($/Unit) for Standard Installation			
	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,964	$2,591	$2,643	$2,696
180	$1,869	$2,496	$2,549	$2,601
180	$1,793	$2,421	$2,473	$2,525
199	$1,898	$2,525	$2,577	$2,630
199	$1,756	$2,383	$2,436	$2,488

Table A48. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 4 NY Metro Incremental Cost ($/Unit) for Additional Labor to Relocate Measure			
	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$2,564	$3,192	$3,244	$3,296
180	$2,470	$3,097	$3,150	$3,202
180	$2,394	$3,022	$3,074	$3,126
199	$2,499	$3,126	$3,178	$3,231
199	$2,357	$2,984	$3,037	$3,089

Table A49. Insulation Incremental Costs

2012 (Combined) Results - Incremental			
	Base Cost Factors by Individual Market ($/SF)		
	38	**49**	**60**
Market 4 NY Metro	$2.38	$2.47	$2.56

Table A50. Air-Cooled Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	**NY Metro Incremental Cost ($/Ton) (Categorized by Efficiency (EER)) Baseline EER = 9.60**				
	9.6	**9.9**	**10.2**	**10.52**	**10.7**
50	$0	$235	$471	$722	$863
100	$0	$118	$235	$361	$432
150	$0	$78	$157	$241	$288
200	$0	$48	$96	$147	$176
400	$0	$24	$48	$74	$88

Table A51. Water-Cooled Screw/Scroll Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	**NY Metro Incremental Cost Estimates (Categorized by Efficiency (kW/Ton) Baseline Efficiency: 0.78 kW/Ton**				
	0.78	**0.72**	**0.68**	**0.64**	**0.6**
50	$0	$78	$130	n/a	n/a
100	$0	$39	$65	n/a	n/a
150	$0	$26	$43	n/a	n/a
200	n/a	$0	$63	$126	$189
400	n/a	$0	$31	$63	$94

TableA52. Water-Cooled Centrifugal Chiller Incremental Costs

2012 (Combined) Results - Incremental				
Capacity (Tons)	NY Metro Incremental Cost Estimates (Categorized by Efficiency (kW / Ton)) Baseline Efficiency: 0.64 kW / Ton			
	0.64	**0.6**	**0.58**	**0.54**
100	$0	$76	$113	$189
150	$0	$50	$76	$126
200	$0	$38	$57	$94
300	$0	$63	$94	$157
600	$0	$31	$47	$78

Table A53. Economizer Incremental Costs- Scenario A

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	NY Metro Incremental Costs		
	Single Enthalpy Economizer	Dual Enthalpy Economizer Controls	Measure Total
5	$796	$221	$1,017
15	$1,305	$296	$1,601
25	$1,814	$371	$2,185
40	$2,577	$484	$3,061
70	$4,103	$709	$4,813
Note: Costs are adjusted to account for material and labor costs.			

Table A54. Economizer Incremental Costs- Scenario B

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	NY Metro Incremental Costs ($/Ton)		
	Dual Enthalpy Control	Dual Enthalpy Control Installation	Measure Total
5	$109	$111	$221
15	$185	$111	$296
25	$260	$111	$371
40	$373	$111	$484
70	$598	$111	$709
Note: Costs are adjusted to account for material and labor costs.			

TableA55. VFD Incremental Costs

2012 (Combined) Results - Incremental			
Size (HP)	NY Metro Incremental Costs ($/Unit)		
	Equipment Cost	Labor Cost	Total Installed Cost
5	$1,152	$1,762	$2,913
15	$2,254	$1,762	$4,016
25	$3,357	$1,762	$5,119
50	$5,616	$1,762	$7,378
75	$7,639	$1,762	$9,401
100	$9,138	n/a	n/a
200	$15,802	n/a	n/a

Table A56. Residential Ductless Minisplit Full Costs

2012 (Combined) Results – Full Cost				
Size (Tons)	NY Metro Full Cost ($/Unit)			
	13 SEER	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$3,738	$4,095	$4,258	$4,489
1	$3,811	$4,157	$4,434	$4,389
1.5	$4,031	$4,401	$4,675	*
2	$4,296	$4,917	*	*

Note: Full costs include a factor labor cost of $2,737/unit for all SEERS in the NY Metro market.

A57. Residential Ductless Minisplit Incremental Costs

Size (Tons)	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$356	$520	$751
1	$346	$623	$578
1.5	$370	$644	*
2	$621	*	*

Table A58. ENERGY STAR Ventilation Fan Material Incremental Costs

2012 (Combined) Results - Incremental			
Feature	NY Metro Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$83	$71	$58
Fan with Light	$127	$115	$102

Table A59. ENERGY STAR Ventilation Fan Full Installation Cost for Replacement Vent Fan

2012 (Combined) Results - Incremental			
Feature	NY Metro Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$427	$460	$491
Fan with Light	$470	$503	$533

Table A60. ENERGY STAR Ventilation Fan Full Installation Cost for New Vent Fan

2012 (Combined) Results - Incremental			
Feature	NY Metro Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$829	$863	$893
Fan with Light	$872	$905	$936

A.5 Market 5: NY Upstate Incremental Costs

Table A61. Combination Heat and Hot Water Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 5 NY Upstate Incremental Cost ($/Unit) (Baseline = Standard Hot Water Boiler, 80 AFUE)			
	90 CAE	91 CAE	93 CAE	95 CAE
110	$1,774	$2,050	$2,602	$3,155
120	$1,829	$2,105	$2,658	$3,210
126	$1,862	$2,138	$2,691	$3,243
150	$1,995	$2,271	$2,823	$3,376
199	$2,266	$2,542	$3,094	$3,647

Table A62. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
	Market 5 NY Upstate Incremental Cost ($/Unit) for Standard Installation			
Size (MBH)	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,711	$2,311	$2,361	$2,411
180	$1,621	$2,221	$2,271	$2,321
180	$1,549	$2,148	$2,198	$2,248
199	$1,648	$2,248	$2,298	$2,348
199	$1,513	$2,113	$2,163	$2,213

Table A63. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
	Market 5 NY Upstate Incremental Cost ($/Unit) for Additional Labor to Relocate Measure			
Size (MBH)	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$2,099	$2,699	$2,749	$2,799
180	$2,009	$2,608	$2,658	$2,708
180	$1,936	$2,536	$2,586	$2,636
199	$2,036	$2,636	$2,686	$2,736
199	$1,901	$2,500	$2,550	$2,600

Table A64. Insulation Incremental Costs

2012 (Combined) Results - Incremental			
	Base Cost Factors by Individual Market ($/SF)		
	38	49	60
Market 5 NY Upstate	$1.90	$1.99	$2.08

Table A65. Air-Cooled Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	NY Upstate Incremental Cost ($/Ton) (Categorized by Efficiency (EER)) Baseline EER = 9.60				
	9.6	9.9	10.2	10.52	10.7
50	$0	$226	$453	$694	$830
100	$0	$113	$226	$347	$415
150	$0	$75	$151	$231	$277
200	$0	$46	$92	$141	$169
400	$0	$23	$46	$71	$85

Table A66. Water-Cooled Screw/Scroll Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	NY Upstate Incremental Cost Estimates (Categorized by Efficiency (kW/Ton) Baseline Efficiency: 0.78 kW/Ton				
	0.78	0.72	0.68	0.64	0.6
50	$0	$75	$125	n/a	n/a
100	$0	$38	$63	n/a	n/a
150	$0	$25	$42	n/a	n/a
200	n/a	$0	$61	$121	$182
400	n/a	$0	$30	$61	$91

Table A67. Water-Cooled Centrifugal Chiller Incremental Costs

2012 (Combined) Results - Incremental				
Capacity (Tons)	NY Upstate Incremental Cost Estimates (Categorized by Efficiency (kW / Ton)) Baseline Efficiency: 0.64 kW / Ton			
	0.64	0.6	0.58	0.54
100	$0	$73	$109	$182
150	$0	$48	$73	$121
200	$0	$36	$54	$91
300	$0	$60	$90	$151
600	$0	$30	$45	$75

Table A68. Economizer Incremental Costs- Scenario A

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	NY Upstate Incremental Costs		
	Single Enthalpy Economizer	Dual Enthalpy Economizer Controls	Measure Total
5	$765	$177	$942
15	$1,254	$249	$1,504
25	$1,743	$322	$2,065
40	$2,477	$430	$2,907
70	$3,944	$647	$4,591
Note: Costs are adjusted to account for material and labor costs.			

Table A69. Economizer Incremental Costs- Scenario B

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	NY Upstate Incremental Costs ($/Ton)		
	Dual Enthalpy Control	Dual Enthalpy Control Installation	Measure Total
5	$105	$72	$177
15	$177	$72	$249
25	$250	$72	$322
40	$358	$72	$430
70	$575	$72	$647
Note: Costs are adjusted to account for material and labor costs.			

Table A70. VFD Incremental Costs

2012 (Combined) Results - Incremental			
Size (HP)	NY Upstate Incremental Costs ($/Unit)		
	Equipment Cost	Labor Cost	Total Installed Cost
5	$1,101	$1,137	$2,237
15	$2,155	$1,137	$3,292
25	$3,209	$1,137	$4,346
50	$5,369	$1,137	$6,505
75	$7,303	$1,137	$8,439
100	$8,735	n/a	n/a
200	$15,106	n/a	n/a

Table A71. Residential Ductless Minisplit Full Costs

2012 (Combined) Results - Incremental				
Size (Tons)	NY Upstate Full Cost ($/Unit)			
	13 SEER	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$2,723	$3,063	$3,220	$3,441
1	$2,792	$3,123	$3,388	$3,345
1.5	$3,002	$3,356	$3,618	*
2	$3,256	$3,850	*	*

Note: Full costs include a factor labor cost of $1,766/unit for all SEERS in the NY Upstate market.

A72. Residential Ductless Minisplit Incremental Costs

Size (Tons)	18 SEER	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$341	$497	$718
1	$330	$596	$552
1.5	$354	$616	*
2	$593	*	*

TableA73. ENERGY STAR Ventilation Fan Material Incremental Costs

2012 (Combined) Results - Incremental			
Feature	NY Upstate Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$80	$68	$56
Fan with Light	$122	$110	$98

TableA74. ENERGY STAR Ventilation Fan Full Installation Cost for Replacement Vent Fan

2012 (Combined) Results - Incremental			
Feature	NY Upstate Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$323	$356	$385
Fan with Light	$366	$398	$427

TableA75. ENERGY STAR Ventilation Fan Full Installation Cost for New Vent Fan

2012 (Combined) Results - Incremental			
Feature	NY Upstate Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$583	$615	$644
Fan with Light	$625	$658	$687

A.6 *Market 6: Mid-Atlantic Incremental Costs*

Table A76. Combination Heat and Hot Water Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 6 Mid-Atlantic Incremental Cost ($/Unit) (Baseline = Standard Hot Water Boiler, 80 AFUE)			
	90 CAE	91 CAE	93 CAE	95 CAE
110	$1,646	$1,925	$2,483	$3,042
120	$1,701	$1,981	$2,539	$3,098
126	$1,735	$2,014	$2,573	$3,131
150	$1,869	$2,148	$2,707	$3,265
199	$2,143	$2,422	$2,980	$3,539

Table A77. Condensing On Demand Water Heater Incremental Costs

2012 (Combined) Results - Incremental				
Size (MBH)	Market 6 Mid-Atlantic Incremental Cost ($/Unit) for Standard Installation			
	Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$1,688	$2,294	$2,345	$2,395
180	$1,596	$2,203	$2,253	$2,304
180	$1,523	$2,130	$2,180	$2,231
199	$1,624	$2,231	$2,281	$2,332
199	$1,487	$2,094	$2,144	$2,195

Table A78. Condensing On Demand Water Heater Incremental Costs

Size (MBH)	2012 (Combined) Results - Incremental Market 6 Mid-Atlantic Incremental Cost ($/Unit) for Additional Labor to Relocate Measure Standard On Demand Water Heater (82 EF)	Condensing On Demand Water Heater (94 EF)	Condensing On Demand Water Heater (95 EF)	Condensing On Demand Water Heater (96 EF)
180	$2,032	$2,639	$2,689	$2,740
180	$1,941	$2,547	$2,598	$2,648
180	$1,868	$2,474	$2,525	$2,575
199	$1,969	$2,575	$2,625	$2,676
199	$1,832	$2,438	$2,488	$2,539

Table A79. Insulation Incremental Costs

	2012 (Combined) Results - Incremental Base Cost Factors by Individual Market ($/SF) 38	49	60
Market 6 Mid-Atlantic	$1.83	$1.92	$2.01

Table A80. Air-Cooled Chiller Incremental Costs

Capacity (Tons)	2012 (Combined) Results - Incremental Mid-Atlantic Incremental Cost ($/Ton) (Categorized by Efficiency (EER)) Baseline EER = 9.60 9.6	9.9	10.2	10.52	10.7
50	$0	$229	$457	$701	$838
100	$0	$114	$229	$350	$419
150	$0	$76	$152	$234	$279
200	$0	$47	$93	$143	$171
400	$0	$23	$47	$71	$85

Table A81. Water-Cooled Screw/Scroll Chiller Incremental Costs

2012 (Combined) Results - Incremental					
Capacity (Tons)	Mid-Atlantic Incremental Cost Estimates (Categorized by Efficiency (kW/Ton) Baseline Efficiency: 0.78 kW/Ton				
	0.78	0.72	0.68	0.64	0.6
50	$0	$76	$126	n/a	n/a
100	$0	$38	$63	n/a	n/a
150	$0	$25	$42	n/a	n/a
200	n/a	$0	$61	$122	$183
400	n/a	$0	$31	$61	$92

TableA82. Water-Cooled Centrifugal Chiller Incremental Costs

2012 (Combined) Results - Incremental				
Capacity (Tons)	Mid-Atlantic Incremental Cost Estimates (Categorized by Efficiency (kW / Ton)) Baseline Efficiency: 0.64 kW / Ton			
	0.64	0.6	0.58	0.54
100	$0	$73	$110	$183
150	$0	$49	$73	$122
200	$0	$37	$55	$92
300	$0	$61	$91	$152
600	$0	$30	$46	$76

Table A83. Economizer Incremental Costs- Scenario A

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	Mid-Atlantic Incremental Costs		
	Single Enthalpy Economizer	Dual Enthalpy Economizer Controls	Measure Total
5	$773	$170	$943
15	$1,267	$243	$1,510
25	$1,761	$316	$2,077
40	$2,502	$426	$2,927
70	$3,984	$645	$4,628
Note: Costs are adjusted to account for material and labor costs.			

Table A84. Economizer Incremental Costs- Scenario B

2012 (Combined) Results - Incremental			
HVAC System Capacity (Tons)	Mid-Atlantic Incremental Costs ($/Ton)		
	Dual Enthalpy Control	Dual Enthalpy Control Installation	Measure Total
5	$106	$64	$170
15	$179	$64	$243
25	$252	$64	$316
40	$362	$64	$426
70	$581	$64	$645
Note: Costs are adjusted to account for material and labor costs.			

Table A85. VFD Incremental Costs

2012 (Combined) Results - Incremental			
Size (HP)	Mid-Atlantic Incremental Costs ($/Unit)		
	Equipment Cost	Labor Cost	Total Installed Cost
5	$1,115	$1,010	$2,125
15	$2,183	$1,010	$3,193
25	$3,250	$1,010	$4,260
50	$5,438	$1,010	$6,448
75	$7,397	$1,010	$8,407
100	$8,848	n/a	n/a
200	$15,301	n/a	n/a

Table A86. Residential Ductless Minisplit Full Costs

2012 (Combined) Results – Full Cost				
Size (Tons)	Mid-Atlantic Full Cost ($/Unit)			
	13 SEER	18 SEER (Lowest SEER with Strong NSTAR Representation)	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$2,536	$2,881	$3,039	$3,262
1	$2,606	$2,941	$3,209	$3,165
1.5	$2,819	$3,176	$3,441	*
2	$3,075	$3,675	*	*
Note: Full costs include a factor labor cost of $1,569/unit for all SEERS in the Mid-Atlantic market.				

Table A87. Residential Ductless Minisplit Incremental Costs

Size (Tons)	18 SEER (lowest SEER with strong NSTAR representation)	21 SEER (Most Represented)	26 SEER (Best Available)
3/4	$344	$502	$726
1	$334	$602	$558
1.5	$358	$622	*

Table A88. ENERGY STAR Ventilation Fan Material Incremental Costs

2012 (Combined) Results - Incremental			
Feature	Mid-Atlantic Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$81	$69	$56
Fan with Light	$123	$111	$99

Table A89. ENERGY STAR Ventilation Fan Full Installation Cost for Replacement Vent Fan

2012 (Combined) Results - Incremental			
Feature	Mid-Atlantic Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$305	$338	$367
Fan with Light	$348	$381	$410

Table A90. ENERGY STAR Ventilation Fan Full Installation Cost for New Vent Fan

2012 (Combined) Results - Incremental			
Feature	Mid-Atlantic Incremental Cost ($/Unit)		
	50 - 89 CFM	90 - 149 CFM	150 - 310 CFM
Exhaust Only	$536	$569	$598
Fan with Light	$579	$611	$641

Appendix B. Premium Pricing in Residential Air Conditioning Under Separate Cover

Under separate cover