Northeast Energy Efficiency Partnerships

Incremental Cost Study Phase Three Final Report

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

May 28, 2014

About NEEP & the Regional EM&V Forum

REGIONAL EVALUATION,
MEASUREMENT & VERIFICATION FORUM

NEEP was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate energy efficiency in the building sector through public policy, program strategies and education. Our vision is that the region will fully embrace energy efficiency as a cornerstone of sustainable energy policy to help achieve a cleaner environment and a more reliable and affordable energy system.

The Regional Evaluation, Measurement and Verification Forum (EM&V Forum or Forum) is a project 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 the Mid-Atlantic region.

About Navigant Consulting Inc.

This report was developed and prepared by Navigant Consulting Inc. (Navigant) for the Regional EM&V Forum, with guidance and assistance from NEEP, Rouleau Consulting and Jacobson Energy on behalf of NEEP. Navigant is the leading Demand Side Management consultant company in research, planning and evaluation, providing services to program administrators across North America. The report authors wish to acknowledge the cooperation and assistance of the study sponsors, who have provided invaluable input and assistance in all phases of the Incremental Cost Studies from 2010 to the present.

Incremental Cost Study
Phase Three Final Report

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

Prepared for

The Evaluation, Measurement and Verification Forum
Chaired by the Northeast Energy Efficiency Partnerships

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Glossary of Terms

ACH = Air Changes per Hour
AFUE = Annual Fuel Utilization Efficiency
ASHP = Air-Source Heat Pump
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
HPWH = Heat Pump Water Heater
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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Subcommittee and Technical Advisory Groups (TAGs) for the Incremental Cost Project

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Peer Reviewers Group

- Whitney Brougher, National Grid
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1. Introduction

This report presents the results of the Third Phase Incremental Cost Study (ICS3) 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 Three follows the Phase One 2010-2011 ICS, and the Phase Two research conducted in 2012-2013. The prior studies can be found at http://neep.org/forum.

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 as well as the incremental costs of moving from baseline to efficient measures. The Phase Three project investigated five additional measures, selected through a process that reviewed 32 potential measures and ranked them on a multi-criteria basis.[1] The final candidate measures were reviewed by Navigant Consulting, Inc. (Navigant) technology experts, Northeast Energy Efficiency Partnerships, Inc. (NEEP) advisors, project sponsor peer reviewers, with final approval by the EM&V ICS3 Subcommittee.

The project results are provided in multiple formats:

- The project report describes the methods and results of the ICS Phase Three study, and addresses a number of cost and research issues that impacted the study along the way.
- Base Cost Factors (BCFs)[2] for each study measure are presented in the report body and a complete set of cost tables is sorted by market in the linked Summary Workbook.
- The full workbooks, including raw data collected, data analysis, and final costs developed for these measures can be found on the Regional EM&V Forum website at http://neep.org/forum.
- A Summary Workbook presents the characterization and summary tables for each project measure.

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 NEEP staff, and assisted by Subcommittee members and technical staff of the member organizations.

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

- Retrospectively assess program cost-effectiveness.

[1] The measure ranking process and results are presented in Appendix A.

[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.

» Prospectively estimate potential program cost-effectiveness to inform which measures and/or programs should be part of efficiency program portfolios.

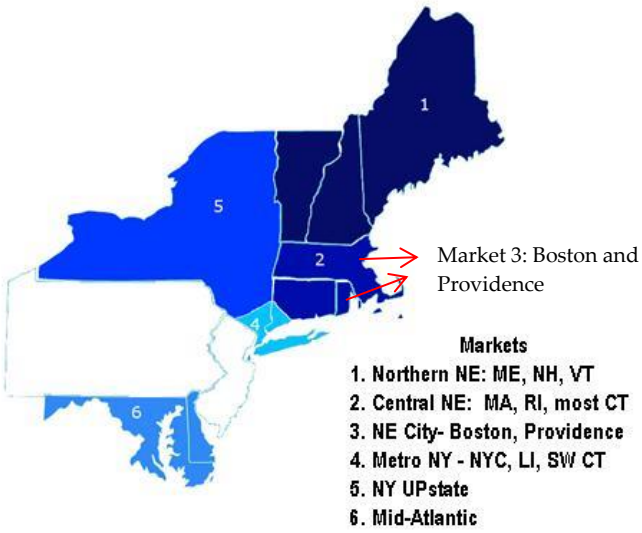
» Inform program design, particularly, the determination of financial incentive levels.

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. 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 Regional Transmission Organization, 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.

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[3]. The study included: New England, New York, and the Mid-Atlantic states of Maryland and Delaware, as well as the District of Columbia. Figure 1 shows the six markets identified.

[3] RS Means, a service of Reed Construction Data, provides market by market equipment and labor cost information across North America

Figure 1. ICS Markets



Source: R.S. Means 2014

Table 1. Project Markets and Cost Factors

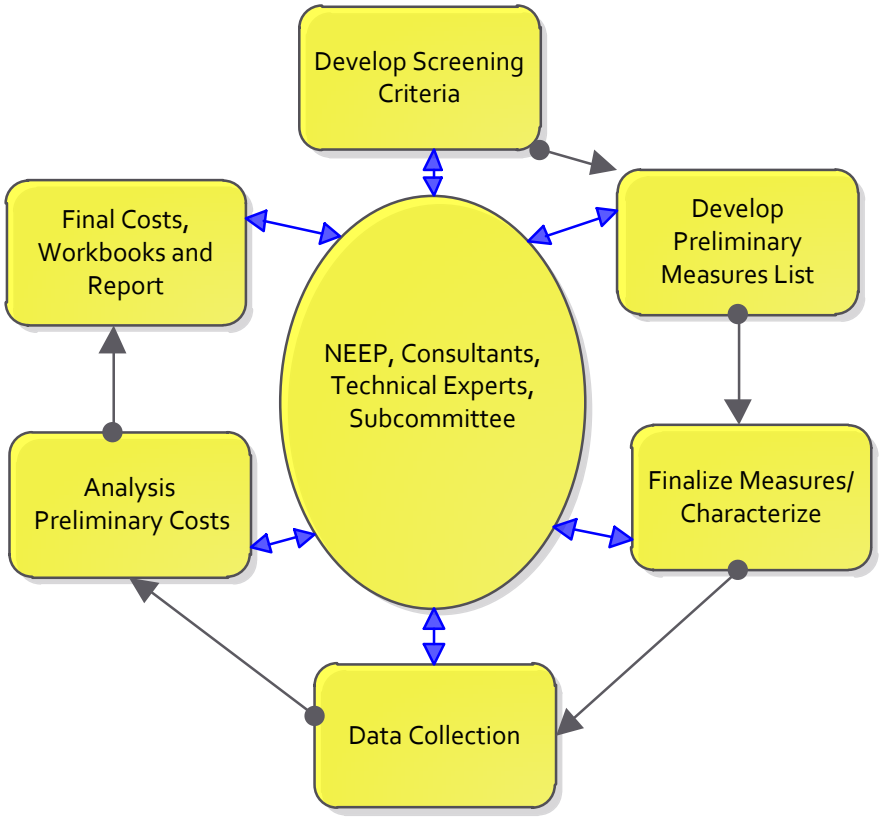
Market	Market Code	Market Territory	Material Adjustment Factor*	Labor Adjustment Factor*
Northern New England	1	ME, VT, NH	0.98	0.82
Central/Southern New England	2	MA , RI, most CT	0.98	1.16
New England City	3	Boston, Providence	1.01	1.28
Metro New York	4	NYC, metro suburbs Southwest CT	1.03	1.56
Upstate New York	5	Albany, Buffalo, Rochester, balance of the state	0.99	1.01
Mid-Atlantic	6	MD, DE, DC	0.99	0.89
Base Cost Factor (BCF)*	NA	-	1.00	1.00

*BCF material and labor cost factors are used to normalize data collected from different markets for analysis on a single platform.

2. Project Design

Like previous phases, ICS3 used a highly interactive project design, in which Navigant sought input from NEEP and technical advisors, expert peer reviewers, and members of the Research Subcommittee. At each stage, Navigant's findings/recommendations were reviewed by multiple parties and where needed, were adjusted in response to observations and comments received. The project was intended to research measures offered prescriptively by project sponsors, rather than surveying the entire market. Figure 2 shows the project design graphically.

Figure 2. Project Design



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2.1 Use of the Incremental Cost Study

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 ICS3 was structured to be more flexible, 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, Navigant has estimated and indicated the likely persistence of the costs determined in this study for factors besides normal inflation adjustments. Section 6-Incremental Cost "Shelf Life"

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.

2.1.1 Summary of Measures Studied in the ICS Phase Three Study

The ICS Phase Three considered a total of five measures. Three measures were commercial and industrial (C&I) electric, one was C&I gas, and one was residential electric. Table 2 briefly summarizes all measures.

Table 2. ICS Phase Three Measures

Measure	Sector	Fuel	Application	Cost Type
Air Source Heat Pumps	C&I	Electric	ROB, NC	Inc.
LED Refrigeration Case Lighting	C&I	Electric	RET[4]	Full
Unitary AC	C&I	Electric	ROB, NC	Inc.
Steam Traps	C&I	Gas	ROB, NC	Full[5]
Heat Pump Water Heaters	Res	Electric	ROB, NC	Inc.

KEY: RET = retrofit, ROB = replace on burnout, NC = new construction, INC = incremental costs, Full = full costs.

[4] A federal rule change on refrigeration case lighting power requirements resulted in some jurisdictions changing the New Construction baseline to LED. However, some manufacturers continue to produce T8 refrigeration cases that meet the new requirement.

[5] Steam traps have no "efficient" alternative. Cost scenario is replacement only, and full equipment and labor costs are included.

3. ICS Research Methodology and Process: Continuity and Changes

Although the overall approach to data collection and analysis for the ICS3 did not change, Navigant made some modifications to the study design and process. The two primary changes were as follows:

» **Development of a scored matrix of potential measures.** The scored matrix was developed to produce a ranked list of measure candidates for review. In this process, Navigant researched 32 measures using the criteria shown in Table 3.

Table 3. Measure Screening Criteria

Criterion	Initial Weight
Level of Specificity	15%
Currently Offered by Program Administrators	30%
Codes and Standards Upgrade	20%
Contribution to Portfolio Savings	20%
Cost Stability Expectation	15%

The complete description of the measure screening process is found in Appendix A.

» **Data collection protocol.** In previous ICS Phases, the research team found substantial difficulty reaching measure installers to secure interviews. Response rates for installers ranged from 5 to 12 percent. Because of those difficulties, in ICS3, data collection shifted to a two- stage process. In the first stage, Navigant conducted in-depth paid interviews with installers, aiming for two completed interviews per measure. In-depth interviews focused on the following:

- Confirming measure baselines.
- Further defining the efficient measure boundaries (e.g., Is ancillary equipment essential to the "typical"[6] installation?).
- Defining the typical installation and in some cases a more complex installation (e.g., heat pump water heater [HPWH]).
- Typical labor hours and rates (plus a sense of the variances encountered).
- Any special measure characteristics that might impact costs.
- Data points for the cost analysis.

[6] "Typical" in this usage is defined for installers as what happens in "80% of installations", the great majority. This approach is taken to avoid focusing on extreme situations.

In the second stage, Navigant collected measure cost data, primarily in the form of equipment invoices and database extracts provided by program administrators and/or implementation contractors. Navigant attempted to gain a broad representation of measures from program administrators. Program administrators did not all offer all five ICS3 measures. Table 4 shows the number of usable data points by measure and by program administrator.

Table 4. Data Points by Measure and Program Administrator

Program Administrator	Steam Traps	Unitary AC	Air Source Heat Pump	Heat Pump Water Heater	LED Refrigeration Case Lighting
BGE		16(16)	2()	467(489)	
Con Ed			2 (3) commercial 1(16)residential		18 (500)
Internet	8 (250)				2 (2)
National Grid	100 (100)	57(57)	2 (6) custom	318 (354)	
NSTAR		19(19)		447 (1,286)	28 (58)
NU					
NYSEG					
PEPCO			3(3)		8 (8)
VEIC					50(50)
Interviews	34 (70)	28(28)	5 (8)	12 (12)	50(50)
TOTAL	**142 (320)**	**120 (120)**	**12 (34)**	**1244 (2141)**	**156 (588)**

Note: Data in parentheses indicate number of total data points collected. Usable data points of totals shown without parenthesis.

Using R.S. 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 peer reviewers and adjusted in response to their comments and issues, where appropriate. Peer reviewers 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.

4. Measure Characterizations and Costs

This section includes ICS3 measure characterizations and costs. The Navigant research team characterized the project measures, with initial inputs from in-house experts, sponsor technical experts, and knowledgeable installers. Draft characterizations were reviewed by peer reviewers and modified as appropriate. Some characterizations were further modified in the research and analysis process.

Note on Costs. Because there are six markets, requiring multiple tables for each measure, in this section we report only the Base Cost Factor (BCF) for each measure. The BCF is the normalized data from which individual market costs are derived. These BCF tables are provided to indicate the approximate costs for each measure but are not the costs for any market. Equipment costs do not vary greatly from market to market but installation costs vary substantially. Full costs for each market and measure are found in the Summary Workbook and the individual measure analysis workbooks, which are available at www.neep.org/EM&V-forum.

Table 5 through Table 14 show each characterization and BCF. Each table is marked as Incremental or Full Cost, depending upon the scenario. Incremental Costs are found where the scenarios are Replace on Burnout (ROB) or New Construction (NC). Full costs are provided for Retrofit scenarios.

4.1 Life Cycle Cost Considerations

The Incremental cost study has focused upon the equipment purchase and installation costs of energy efficiency measures. These measures are good guides for setting incentive costs in energy efficiency programs. However, typical benefit cost calculations do not consider some life-cycle implications, such as comparative operations and maintenance (O&M) costs or greatly differing expected measure lives, which are relevant to some measures. For example, ICS3 examined light emitting diode (LED) refrigeration case lighting, which most often involves retrofitting case lighting from T8 to LED. LED lighting has a much longer measure life than T8 lighting and in considering the baseline T8 costs; we determined that the cost should include an adjustment for a ballast replacement, to bring the estimated measure lives of both measure types into closer alignment. This adjustment resulted in an approximate 4 percent decrease in the incremental measure cost. We did not take into account compact fluorescent lamp (CFL) replacement, since the cost of CFL bulbs is only a few dollars and would not significantly affect either baseline cost or cost/benefit calculations. The other Phase Three measures do not exhibit this measure life disparity and, therefore, require no adjustment. Navigant will consider this issue for Phase Four measures as well.

4.2 Commercial Air Source Heat Pump – Electric

Table 5. Commercial Air Source Heat Pump Characterization

Measure Description	Commercial air source heat pump
Baseline	Standard efficient air source heat pump
Measure Scenario(s)	ROB, NC
Baseline Efficiency Levels	International Energy Conservation Code (IECC) 2009 and/or jurisdiction-specific (IECC 2012 did not make any substantial change to the baseline requirement.) Baseline efficiencies vary by size.
Measure Level Description	High-efficiency split or packaged air source Heat pumps meeting CEE Tier requirements
Measure Efficiency Levels	Consortium for Energy Efficiency (CEE) Tier 1 & Tier 2 Tier 2 for units with capacities larger than 65,000 Btu/h is based on the Cool Choice program.
Sizes (1 ton = 12,000 Btu/h of cooling)	3 tons
	4 tons
	5 tons
Distinguishing Features	With or without electric resistance backup Heating
Installation Scenarios	Split system or single package
Sources	NY Technical Reference Manual (TRM), Efficiency Maine TRM, Massachusetts TRM
Comments	DX or VRF, ducted only, non-ducted (e.g., mini-splits) excluded. There are no incremental labor costs for this measure

Table 6. Commercial Air Source Heat Pump Base Cost Factor

Size Category (Tons: 12,000 BTU= 1 ton)	Base Cost Factor - BCF ($/Unit)	
	CEE Tier 1	CEE Tier 2
3	$467.99	$935.98
4	$467.99	$935.98
5	$467.99	$935.98

Note: Costs are Incremental for ROB and NC.

4.3 Commercial LED Refrigeration Case Lighting - Electric

Table 7. LED Refrigeration Case Lighting

Measure Description	Light-Emitting Diode (LED) Refrigeration Case Lighting
Baseline	Standard Case Lighting (T12HO or standard T8) For Life Cycle purposes baseline cost assumes one ballast replacement as O&M, resulting approximately 4% incremental cost reduction. Replacement CFLS not considered in baseline costs because they are minimal.
Measure Scenario(s)	RET
Baseline Efficiency Levels	RET = Existing lighting
Measure Level Description	LED lighting is installed in place of linear fluorescent lighting in horizontal or vertical refrigeration display cases.
Measure Efficiency Levels	Standard LED vs. Design Lights Consortium Qualified Products list
Sizes	Per unit, per door, or per foot
Distinguishing Features	Vertical or horizontal display case (per door or per linear foot)
Sources	ME TRM, Mid-Atlantic Technical Reference Manual (TRM), EVT offerings, and NY TRM
Comment	Energy Conservation Program: Test Procedure for Commercial Refrigeration Equipment. Federal Register / Vol. 77 , No. 34 / Tuesday, February 21, 2012 /Rules and Regulations. This change to power standards LED's the baseline for New Construction in some jurisdictions but there are T8 units that meet this standard, so there can be a New Construction case with LED's as the efficient measure.

Table 8. Commercial LED Refrigeration Case Base Cost Factor

Base Cost Factor	Efficient Measure Full Material Cost		
	Cost per Unit ($/LED)	Cost per Foot ($/ft.)	Cost per Door ($/door)
Vertical - Center	$157.82	$30.92	$210.43
Vertical - End	$120.54	$23.70	$160.72
Horizontal	$118.49	$24.31	
Overall	$136.10	$26.99	$187.50

2013 Results - Labor

Base Cost Factor	Efficient Measure Labor Cost		
	Cost per Unit ($/LED)	Cost per Foot ($/ft.)	Cost per Door ($/door)
Vertical - Center	$33.75	$6.84	$45.00
Vertical - End	$33.75	$6.84	$45.00
Horizontal	$33.75	$6.84	
Overall	$33.75	$6.84	$45.00

2013 (Combined) Results - Incremental

Base Cost Factor	Efficient Measure Incremental Cost		
	Cost per Unit ($/LED)	Cost per Foot ($/ft.)	Cost per Door ($/door)
Vertical - Center	$143.63	$28.43	$191.51
Vertical - End	$106.35	$21.10	$141.80
Horizontal	$104.30	$21.55	
Overall	$121.91	$24.39	$168.58

Note: Costs are full for Retrofit (RET) and Incremental for NC.

4.4 Commercial Unitary Air Conditioning - Electric

Table 9. Commercial Unitary Air-Conditioning (AC) Characterization

Measure Description	Commercial Unitary AC (packaged)
Baseline	Standard Efficient Unitary AC
Measure Scenario(s)	ROB, NC
Baseline Efficiency Levels	IECC 2009 and/or jurisdiction-specific. Baseline efficiency varies by size.
Measure Level Description	High-Efficiency Unitary Air-Conditioning Equipment
Measure Efficiency Levels	CEE Tier 1 & Tier 2 (see CEE Criteria Tab)
Sizes (1 ton = 12,000 Btu/h of cooling)	5.4-11.25 tons
	11.25-20 tons
	20 -63 tons
	>= 63 tons
Distinguishing Features	1) Heating type (none, gas, electric resistance)
	2) Other features: (e.g., variable-speed fans and compressors associated with higher energy efficiency ratios [EERs])
Installation Scenarios	Single Package
Sources	NY TRM, Mid-Atlantic TRM, EVT TRM, Efficiency Maine TRM, MA TRM
Comments	Replace Unitary AC only There are no incremental labor costs for this measure.

Table 10. Unitary AC Base Cost Factor

Base Cost Factors

Size Category (Tons)	Non Regional Specific Incremental Cost ($/Ton)	
	CEE Tier 1	CEE Tier 2
5.4 to 11.25	$63.42	$126.84
11.25 to 20	$63.42	$126.84
20 to 63	$18.92	$37.83

Note: Costs are Incremental for ROB and NC

4.5 Commercial Steam Traps: Low-Medium Pressure - Gas

Table 11. Commercial Steam Traps Characterization

Measure Description	Steam Traps
Baseline	Leaky or Failed Steam Trap
Measure Scenario(s)	RET, ROB (there is no "efficient' steam trap alternative.
Baseline Efficiency Levels	Leaky or Failed Steam Trap
Measure Level Description	Newly Installed/Replaced Steam Trap
Measure Efficiency Levels	n/a
Sizes	Pipe diameter ranges between 0.25" and 2".
Distinguishing Features	1) Thermostatic, Thermodynamic, Mechanical, or Fixed-Orifice
	2) Maximum Operating Pressure
Installation Scenarios	Commercial and Industrial Steam Heating Lines (Low and Medium Temperature Applications)
Sources	MA TRM, CA Steam Trap Surveys, Conservation Solutions Interview
Comments	The scope of this characterization excludes steam trap repairs, steam trap surveys, and steam trap testing. The full measure costs include equipment and labor...

Table 12. Commercial Steam Trap Base Cost Factor

Steam Trap Type	Diameter Size (in.)	Steam Traps		Base Cost Factor ($/Unit)
		Material Cost	Labor Cost	Total Installed Cost
Float & Thermostatic	0.5	$308	$197	$506
	0.75	$437	$197	$635
	1	$566	$209	$775
	1.5	$825	$295	$1,120
	2	$1,083	$278	$1,361
Inverted Bucket	0.5	$268	$197	$466
	0.75	$471	$197	$669
	1	$675	$209	$883
	1.5	$1,081	$295	$1,376
	2	$1,487	$278	$1,766
Thermodisc/ Thermodynamic	0.5	$385	$197	$582
	0.75	$535	$197	$732
	1	$685	$209	$894
Thermostatic	0.5	$294	$197	$491
	0.75	$369	$197	$567
	1	$445	$209	$654

Note: This measure includes Full Equipment and Labor Costs are for ROB and NC.

4.6 Residential Heat Pump Water Heaters - Electric

Table 13. Residential Heat Pump Water Heater Characterization

Measure Description	Heat Pump Water Heater	Heat Pump Water Heater
Baseline Description	Baseline **Electric** Resistance storage water heater	Baseline Direct-fired **Natural Gas,** storage water heater
Measure Scenario(s)	ROB, NC	ROB
Baseline Efficiency Levels	RET, ROB or NC: Standard electric resistance storage water heater EF = **0.97 - (0.00132 * Vol. in gal.)**	RET or ROB: Standard Natural Gas, LP or oil storage water heater EF= 0.62
Measure Level Description	Heat Pump storage water heater installed in conditioned or semi-conditioned space ROB: vs. existing electric resistance storage water heater ROB and NC: vs. standard EF electric resistance water heater EF = 0.97 - (0.00132 * Vol. in gal.)	Heat Pump storage water heater installed in conditioned or semi-conditioned space ROB: vs. existing Natural Gas storage water heater ROB: vs. standard EF Natural Gas, LP or oil water heater EF = 0.62
Measure Efficiency Levels	Minimum Specifications: PSNH, NSTAR, Nat. Grid require ENERGY STAR* HPWH with EF >= 2.3, min. 1st hour recovery of 60 gallons. CT L&P, BGE, PEPCO require ENERGY STAR * Heat Pump water heater EF >= 2.0 Con Ed requires EF >= 2.0 only * ENERGY STAR requires EF >= 2.0 and minimum 1st Hour Rating of 50 gallons	Minimum Specifications: PSNH requires ENERGY STAR* HPWH with EF >= 2.3. BGE, PEPCO require ENERGY STAR* HPWH. Con Ed requires EF >= 2.0 only. * ENERGY STAR requires EF >= 2.0 and minimum 1st Hour Rating of 50 gallons.
Sizes	Residential sizes: 50 and 80 gallons	Residential sizes: 50 and 80 gallons
Distinguishing Features	Rebates available to PSNH, NSTAR, BGE, PEPCO, National Grid (MA), CT L&P, and Con Ed customers	Available only to PSNH, BGE, PEPCO, and Con Ed customers
Installation Scenarios	Replacing an electric water heater in conditioned or unconditioned interior space	Replacing a gas or oil-fired water heater in conditioned or unconditioned interior space
Sources	Mid-Atlantic TRM, EVT TRM, NY TRM, ENERGY STAR draft criteria.	EVT TRM, NY TRM, ENERGY STAR draft criteria/
Comments	Base values taken from notice of final rule. 77 FR 74559 (Dec. 17, 2012). Study will accommodate ENERGY STAR and higher efficiency standards in CT, MA, and NH.	Costs include incremental labor

Table 14. Residential Heat Pump Water Heater Base Cost Factor

Baseline Storage Water Heater		Base Cost Factor Incremental Cost ($/Unit)
Gallon Size	Efficiency (EF)	Heat Pump Water Heater (2.00 EF to 2.51 EF)
50	90.4	$1,027.21
60	89.08	$1,089.38
80	86.44	$1,213.73

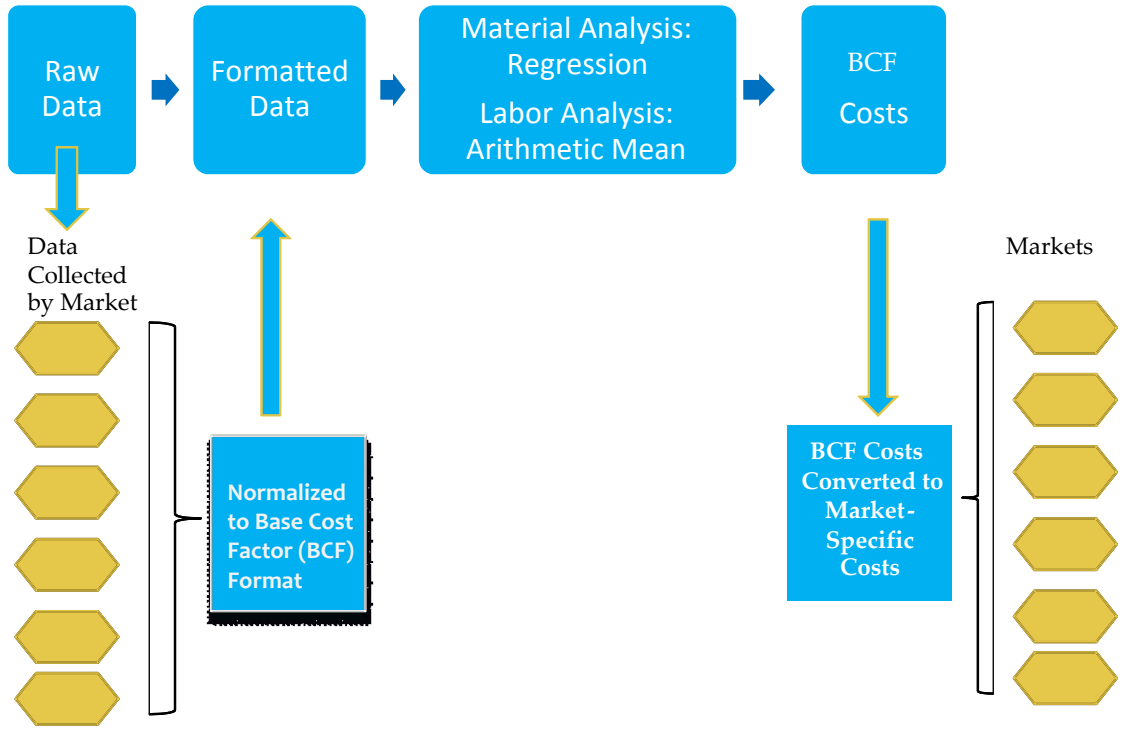
Note: Applicable scenarios for this measure are ROB and NC

5. Data Analysis and Quality Control

Data Analysis and Quality Control for ICS3 did not differ substantively from Phases One and Two. Data collected from program sponsors, installers, and other sources were placed on a single analytic platform. The research team achieved this using RS Means equipment and labor cost factors to adjust data collected in each market. As can be seen in Figure 1 on page 4, equipment costs vary only over a small range, from 0.98 to 1.03. Labor costs, however, are much more variable, ranging from 0.82 in northern New England to 1.56 in the Metro NY market. Figure 3, below, demonstrates the data analysis process.

Once data for each measure were placed on a single analysis platform, Navigant calculated the BCF, using regression analysis or arithmetic means, as most appropriate. The BCF was then adjusted for each market, using equipment factors. For Retrofit scenarios and ROB or NC where the efficient measure requires incremental labor costs, the BCF labor costs were also adjusted for each market.

Figure 3. Cost Analysis Process Including Formatting Base Cost Factor Cost Development and Final Cost Determination for Each Market



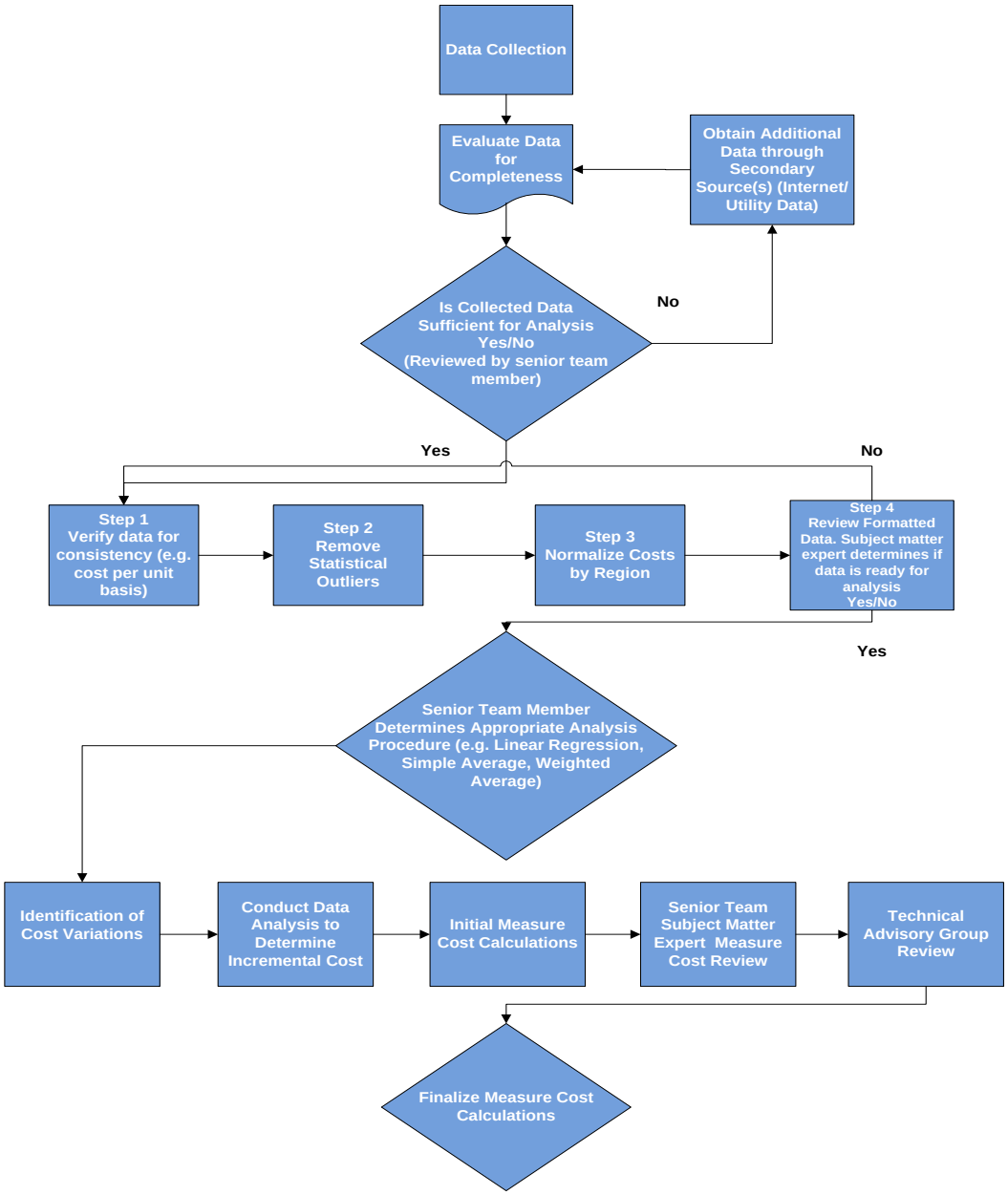
A complete discussion of the data analysis process is found in the *Incremental Cost Study Phase Two* report, available on www.neep.org/EM&V-forum.

The ICS Quality Control process is demonstrated in Figure 4. Once material and labor costs were collected for, the ICS team reviewed the data to ensure all parameters needed to accurately leverage the data for analysis were present. If additional data was required, the team would then collect additional data. If the data collected was sufficient for analysis, the team would move on to the Final Data Review Phase. This phase consisted of; (1) verifying the data for consistency; (2) removal of statistical outliers;

(3) normalizing the costs by region; and (4), review of formatted data by a subject matter expert to determine if the data is ready for the analysis phase. If the subject matter expert determined the formatted data is not ready, the analyst returns to Step (1) – verifying the data for consistency. If the subject matter expert determined the data is ready for analysis, the measure was then ready the Analysis Phase.

The Analysis Phase of Phase 3 began with a senior team member determining the appropriate analysis approach (e.g., linear regression, simple average, and weighted average) based on the formatted data. The next step consisted of identification of cost variations in the formatted data. Once cost variations were determined, the incremental costs were developed using the predetermined analysis methodology (e.g., linear regression, simple average, etc.). The developed incremental costs were then reviewed by a senior team subject matter expert. If the subject matter expert found the analysis and incremental costs reasonable and correct, the measure workbook was then transferred to the TAG for final review and approval.

Figure 4. ICS3 Quality Control Process



Source: Navigant Consulting, Inc. 2014

6. 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)

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 Practice. Table 15 shows expected shelf life for all study measures.

Table 15. Measure Cost Shelf Life

Measure	Expected Cost Life	Comments
Air Source Heat Pumps	Stable	Current DOE Docket: Commercial Air Conditioners and Heat Pumps, Docket No. EERE-2013-BT-STD-0007 for Small (65,000–135,000Btu/h), Large (135,000–240,000), and Very Large (>240,000). Early stage of process – no rule-making date established.
LED Refrigeration Case Lighting	Frequent	Robust technology gaining market share for retrofit. Technology is baseline for New Construction but could change as LED efficacy increases.
Unitary AC	Medium	Federal standards are scheduled to be amended in 2014 with an effective date in 2017.
Steam Traps	Stable	Established Steam Trap technologies should remain the same for foreseeable future. No breakthrough technologies are known that would disrupt the market.
Heat Pump Water Heaters	Stable	Standards changed recently (2009) to all but eliminate electric resistance Domestic Hot Water (DHW. ENERGY STAR no longer qualifies storage electric resistance water heaters.

KEY:
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.

Appendix A. Measure Selection Process

Incremental Cost Study Phase Three
Measure Selection Recommendations
September 6, 2013[7]

Summary

Navigant Consulting, Inc. (Navigant) presents recommendations for five energy efficiency measures for incremental cost study for the 2013 Incremental Cost Study Phase Three (ICS3) for review and adoption by the Evaluation, Measurement and Verification (EM&V) Forum's Research Subcommittee. Navigant makes these recommendations resulting from a process wherein Northeast Energy Efficiency Partnerships, Inc. (NEEP), technical experts, study sponsors, and Navigant provided input on the measure selection criteria.[8] Using the criteria, Navigant then researched and scored 32 energy efficiency measures. We next invited input on scored measures from sponsors and technical experts, and then did an internal ranking, taking all qualitative and quantitative comments and rankings into account. Table lists the recommended measures.

Table A1. Recommended Measures

Rank	Measure	Fuel	Sector
1	Unitary AC 65- 135kBh	Electric	C/I
2	Heat Pump Water Heater	Electric	Res
3	LED Refrigeration Case Lighting	Electric	C/I
4	Steam Traps	Gas	C/I
5	Air Source Heat Pump	Electric	C/I

In addition to these five measures, this process has resulted in the development of a list of measures for consideration in future phases of incremental cost research. Some of these measures were derived from Navigant's measure selection research. Additional measures were suggested by sponsors and other reviewers. These additional measures are provided at the end of this Appendix.

[7] This memo was presented to the EM&V Research Subcommittee September 13, 2013.
[8] The measure criteria development process is fully described in Navigant's memo titled, NEEP ICS 3 *Selection Criteria DRAFT 2013 July15.*

Measure Selection Criteria

Navigant developed six initial criteria, subsequently reduced to five criteria because the Data Availability criterion was determined to be duplicative. As shown in Table , each criterion was provided with a weight. Sponsors and other reviewers commented on the proposed initial weights.

Table A2. Final Measure Selection Criteria

Criterion	Weight
Level of Specificity	15%
Currently Offered by Program Administrators	30%
Codes and Standards Upgrade	20%
Contribution to Portfolio Savings	20%
Cost Stability Expectation	15%

Level of Specificity. All ICS3 measures will be prescriptive, so that measures can be characterized in a manner that will be useful to a number of Program Administrators (PAs), as custom measures cannot. Specificity may be important in two ways. Some measures can be specified across a consistent range of capacities and efficiencies, such as residential furnaces. Other measures may have a variety of possible technologies or configurations, such as chillers, but may be discrete enough to permit an appropriate level of characterization. In making this assessment during the measure selection process, Navigant will review the offerings of participating Program Administrators.

Currently Offered by Program Administrators. This criterion is very important for providing cost research across the greatest range of participating Program Administrators. Navigant recognizes that some measures may be of greater interest to some parts of the total NEEP region than others but other factors may offset measures that currently have more limited use.

Codes and Standards Upgrade. This category has two aspects—code or performance standards—that have recently been upgraded, and measures in which the market or industry practice has moved beyond mandatory federal standards or voluntary standards like ENERGY STAR®. Where mandatory standards have been upgraded very recently or are scheduled to be upgraded, there may not be a great deal of applicable cost data. We have learned from previous research that when measures which were formerly categorized as "efficient" are upgraded to baseline in federal standards, the new baseline measure may transition from a niche part of a measure market to full-scale production, with corresponding impacts on measure costs. Therefore, we believe it is necessary to have enough market experience with the new baseline and efficiency standards to ensure that costs are correctly captured. Navigant will consult with technical experts on this issue, as well as our own technology and regulatory experts. We will also address the issue again in in-depth distributor/installer interviews on the final measures researched in ICS3.

Contribution to Portfolio Savings. This criterion captures measures that contribute significant savings to program portfolios. Given that lighting measures continue to be the overall largest sources of electric savings, Navigant will primarily consider measures savings in the non-lighting portion of portfolio savings, working primarily from recent Program Administrator annual reports. Lighting measures will be considered within the lighting portion of portfolios so there are proportional ratings.

Cost Stability Expectation. This factor can impact measures where changes in codes and standards, technology or markets will impact the measure cost. Navigant proposes to look at a three-year horizon

for this estimation, expecting there will be some changes in all measures researched. We know some categories, however, such as light-emitting diode (LED) lighting, are continuing to evolve rapidly. Nonetheless, even within that broad category, there may be some measures that are becoming more stable that may be worth researching because of their savings impact. For example, screw-in LED lighting is a rapidly evolving technology and may not be suitable to include in ICS3; however, LED strip lighting has become more stable within the marketplace and does warrant investigation.

Characteristics that were noted but were not scored included the following:

- » Fuel Type
- » Customer Sector(s)
- » Applicable Measure Scenario(s)
  - Retrofit (RET)
  - Replacement or Replace on Burnout (ROB)
  - New Construction (NC)

Developing the List of Measure Recommendations

Navigant separately assessed electric and gas measures for the residential and commercial/industrial sectors. All measures received raw and weighted scores. Navigant initiated its list through an internal brainstorming process, consultation with NEEP and NEEP technical advisors, and for LED lighting, a conversation among Navigant and Program Administrator technical experts. This process produced a list of 32 possible measures to address.

With the initial list in hand, Navigant next conducted a review of measures offered across the PAs in the participating states. Program Administrators' prescriptive offerings were tallied and scored for each criterion and the prior agreed-upon weights were applied, providing a total weighted score for each measure. Table A3 presents the initial measure list and the raw and weighted scores for each. Navigant provided all reviewers with an Excel workbook with raw and weighted scores for each measure for each criterion. Table provides this detail for the measures reviewed.

Table A3. Reviewed Measures Showing Raw and Weighted Scores

Measure	Fuel	Res or C/I	Total Raw Score	Weighted Score
Refrigerators	Electric	Res	19	73
Refrig. Glass Door Heater Controls	Electric	C/I	19	72
LED Refrigerator Case Lighting	Electric	C/I	18	71
Unitary ACs 65-135 kBh	Electric	C/I	17	68
Boiler Reset Controls < 300 kBh	Electric	C/I	18	68
Steam/Heat Traps	Natural Gas	C/I	18	68
HP Water Heater	Electric	Res	18	67
ASHP 65-135 kBh	Electric	C/I	17	67
Screw Air Compressor < 40 HP	Electric	C/I	17	65
Com. Refrig./Freezers	Electric	C/I	17	64
Room A/C	Electric	Res	17	63
Furnace with ECM Fan	Electric	Res	16	61
Furnaces 225-500 kBh	Natural Gas	C/I	16	60
LED Screw in PAR	Electric	Res& C/I	15	57
Ground Source Heat Pump	Electric	Res	15	56
Clothes Washers	Electric	Res	15	55
Faucet Aerator	Dual (Electric/Gas)	Res	15	54
Thermostat	Electric	Res	15	53
LED Recessed Fixture	Electric	Res& C/I	14	53
Commercial Clothes Washer	Dual Electric/Gas	C/I	14	52
Air Purifiers	Electric	Res	15	52
Tank Wrap/Pipe Insulation	Natural Gas	Res	14	52
Commercial Dishwashers	Dual (Electric/Gas)	C/I	13	51
Energy Audit	Electric	Res	13	48
Heat Recovery Ventilation	Natural Gas	Res	13	48
On-Demand Electric Water Heater	Electric	Res	13	47
Drain water Heat Recovery	Dual (Electric/Gas)	Res	13	46
Heating Pipe Insulation/Duct Sealing	Natural Gas	Res	12	45
Motors 5-25 HP	Electric	C/I	11	44
Indirect-Fired Water Heater	Natural Gas	Res	13	44
Gas-Fired Space Heater	Natural Gas	Res	11	44
Pipe Insulation	Electric	Res & C/I	11	40

Table A3 shows a very tight distribution among the first eight measures and generally small decrements going down the measure list. The scored list was circulated to all sponsors and advisors for comments, with a request for each organization to submit its preferences and comments on the measures. Responses were received from Efficiency VT, MA Program Administrators, Massachusetts Energy Efficiency Advisory Council (MA EEAC) Consultants, NEEP's Technical Advisor, PEPCO, Con Ed, NYSEG,

NYDPS, NYSERDA, National Grid, and NSTAR. Some organizations provided ranked lists; others expressed their preferences but not in rank order. Some organizations also suggested measures that were not on the list provided.

As a final exercise in the measure selection process, the Navigant team did an internal ranking of the top ten measures, based on the initial scorings, the input provided by sponsors, and the team members' own assessments of the best research candidates. All of these results were tallied and weighted. Where sponsors provided unranked preferences, Navigant made a qualitative adjustment to capture the widest input.

A Note on Refrigerators

Table A4 shows refrigerators as the highest scored measure, but refrigerators are not on the recommended measure list for two reasons. The most important concern is that ENERGY STAR® standards for refrigerators are scheduled to change, effective September 2014. Considering the ICS3 project schedule, refrigerator data would likely only be current for about six months. Consequently, studying refrigerator costs at this time does not appear to be a very cost-effective use of research resources.

The second issue around refrigerators is a potential premium pricing issue, one that the ICS previously encountered with central air conditioning. As with other appliances, efficiency is often bundled with a variety of convenience features. However, Navigant believes the refrigerator market is more commoditized and it should be possible to find Tier Two and Three refrigerators that are not loaded with non-energy features. This issue should be revisited when another opportunity arises for cost research.

Table A1. At the top of this memo presents the list of the five recommended measures.

A.1 Additional Measures for Future Cost Research

Sponsors and other reviewers made several suggestions for measures that were not included in Navigant's researched list. For future consideration, Navigant recommends retaining this list, along with high-scoring measures that will not be researched in Phase Three. Table A4 shows the additional suggested measures.

Table A4. Additional Suggested Measures

Additional Suggested Measure
Clothes Washers (Tiers Two and Three)
Efficient Televisions
LED Wall Packs
LED Outdoor Pole/Arm Area or Roadway Fixture
Engine Block Heater/Timer (Agricultural and Municipal machinery and transportation equipment)