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Northeast Energy Efficiency Partnerships

Incremental Cost Study
Phase Four Final Report

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

June 15, 2015

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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. Led by Mike Sherman, Keith Levenson, Nick Beaman and Randy Gunn, the Navigant team has researched more than 30 energy efficiency measures for the Regional EM&V Form from 2010 to the present.

About Navigant Consulting Inc.

Navigant is a leading Demand Side Management consultant company in smart grid and energy efficiency 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.

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Incremental Cost Study
Phase Four Final Report

A Report on Incremental Costs of Six Energy Efficiency Measures in Six Northeast and Mid-Atlantic Markets

Prepared for

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

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Glossary of Terms

ACFM = Actual Cubic Feet per Minute: *for air compressor systems, a measure of compressed air flow*
ASDHC = Anti-Sweat Door Heater Control
BCF =Base Cost Factor: *Normalization used for data analysis and reporting specific market costs*
Btu = British Thermal Unit
CFM = Cubic Feet per Minute
CPUC = California Public Utility Commission
DOE = U.S. Department of Energy
ECM = Electronically Commutated Motor
EFC = Evaporator Fan Control
EM&V = Evaluation, Measurement, and Verification
HVAC = Heating, Ventilation, and Air-Conditioning
ICS = Incremental Cost Study
ICS4 = Incremental Cost Study Phase Four
IECC = International Energy Conservation Code
kBtu/h = Thousand 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
TAG = Technical Advisory Group
TRC = Total Resource Cost
TRM = Technical Reference Manual
VFD = Variable Frequency Drive

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Preface

The Regional EM&V Forum

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

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1. Introduction

1.1 Incremental Cost Study Phase Four

This report presents the results of the Phase Four Incremental Cost Study (ICS4) 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 Four follows the Phase One ICS in 2010-2011, the Phase Two research conducted in 2012-2013 and Phase Three conducted in 2013-2014. The prior studies can be found at http://www.neep.org/initiatives/emv-forum. To easily access this data, the results of all the individual studies have been compiled in a Master Summary Workbook which is located at the same website.

The ICS study's overall goal was to determine baseline and efficient measure costs for a series of energy efficiency prescriptive measures of interest to the Subcommittee as well as the incremental costs of moving from baseline to efficient measures. The Phase Four project investigated six additional measures, selected from the measures identified in the measure selection process developed in Phase Three that reviewed 32 potential measures and ranked them on a multi-criteria basis. The final candidate measures for ICS Phase Four were reviewed by Navigant Consulting, Inc. (Navigant) technology experts, Northeast Energy Efficiency Partnerships, Inc. (NEEP) advisors, and project sponsor peer reviewers, with final approval by the EM&V ICS4 Subcommittee.

The project results are provided in multiple formats:

- The project report describes the methods and results of the ICS Phase Four study, and addresses a number of research issues and findings that impacted the study.
- 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 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://www.neep.org/initiatives/emv-forum .
- A Master Summary Workbook presents the characterization and summary tables for each project measure in Phase Four and all prior Phases.

1.2 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, as well as 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 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, New York and

[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 this report. These cost factors are developed by R.S. Means and updated annually. In Phase Four, Navigant applied the updated factors to any data collected in previous Phases used in the Phase Four analysis.

Mid-Atlantic regions. The ICS Request for Proposals stated: "The objectives of the Project are to develop electric and gas efficient measure incremental cost assumptions that will improve the ability of efficiency program planners, program administrators, program evaluators and regulators to:

» Retrospectively assess program cost-effectiveness.

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

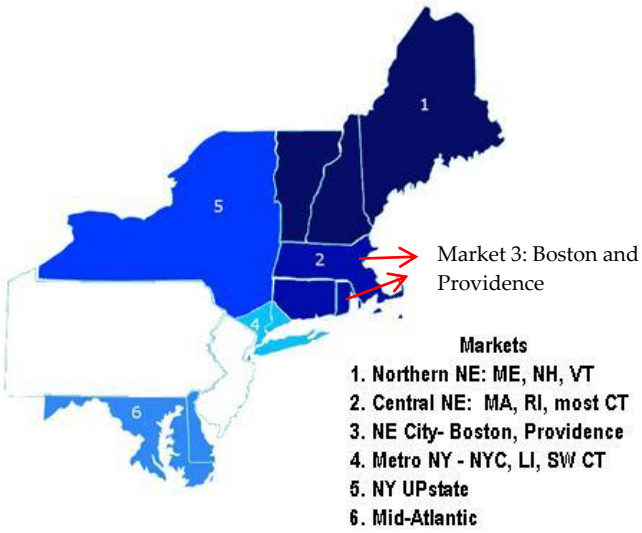
» Inform program design, particularly the determination of financial incentive levels.

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[2] as shown in Table 1. 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 specific markets identified.

[2] R.S. 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	0.99	0.84
Central/Southern New England	2	MA , RI, most of CT	0.99	1.17
New England City	3	Boston, Providence	1.02	1.27
Metro New York	4	NYC, metro suburbs Southwest CT	1.03	1.55
Upstate New York	5	Albany, Buffalo, Rochester, balance of the state	0.99	1.01
Mid-Atlantic	6	MD, DE, DC	1.00	0.88
Base Cost Factor (BCF)*	NA	-	1.00	1.00ss

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

1.3 Recommendations and Use of the Incremental Cost Study

The study team believes the costs presented in this report 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 for Program Administrators. 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 full and 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 ICS4 was structured to be more flexible, creating cost curves that can accommodate scaling by capacity and efficiency. The

study team has provided the workbooks used to develop costs for each measure. The workbooks are completely open and can be updated or customized with Sponsor-specific 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; these are discussed in Section 6.

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, code changes or customer demand for more efficient equipment than the minimum standard.

Finally, the efficient equipment that 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.

1.4 Measure-Specific Recommendations

The focus of the ICS4 was on developing robust incremental costs for each project measure studied. In the course of establishing measure costs, the project team made a number of findings about the measures studied in this Phase, some of which relate to better understanding of measure characteristics and distinctions, and others which derive from developments in the marketplace for measures.

A good example of the former is establishing that there is more than one type of Evaporator Fan Control. There are controls that simply control the status of fans – full speed, low-speed, on or off - which are relatively simple devices. There are also controls which include EFC as one feature in specialized energy management systems, with substantially greater capabilities and also rather different costs.

An example of the latter is the finding that large commercial furnaces have been superseded in the marketplace. Some Program Administrators still offer incentives for large furnaces but they have no uptake, because that equipment as characterized is not available in the market. We also found some negative incremental costs that appear to be attributable to changing offerings and conditions in the marketplace.

Below are some key findings and recommendations regarding program design arising from what we learned in the course of the ICS4. Like the incremental costs themselves, the project team offers these recommendations as advice to Program Administrators, to evaluate in light of prevailing conditions in each service territory.

1.4.1 VFD and Load/No Load Air Compressors

The cost of a baseline (modulating) air compressor is nearly the same as a Load/No Load Air Compressor of the same horsepower, especially below 40 hp. Navigant finds that the market for baseline modulating air compressors is shrinking and that Load/No Load Air Compressors have become the de facto baseline technology. This finding suggests phasing out incentives for Load/No Load air compressors.

1.4.2 Commercial Kitchen Fryers

The market share of non-qualifying (baseline) models in the market place is diminishing making determining an incremental cost less relevant. The ENERGY STAR qualifying criteria is seen as a low threshold for manufacturers to meet, which has resulted in a market saturated with ENERGY STAR rated fryers and diminished importance of the ENERGY STAR label as a distinguishing factor for offering rebates. Commercial Kitchen Convection Ovens

Non-ENERGY STAR convection ovens also appear to be rapidly declining in the marketplace for the same reasons as commercial fryers, and some manufacturers now provide only ENERGY STAR compliant units. The Navigant study yielded a negative incremental cost estimate for Commercial Convection Ovens due to the discontinuation of basic non-qualifying models and the continued demand for extra-durable high-end non-ENERGY STAR equipment. Basically this means that it now costs more to purchase a lower efficiency convection oven which may be more durable than it is to purchase a higher efficiency ENERGY STAR qualified model.

1.4.3 Refrigeration Anti-Sweat Heater Controls

The market for Anti-Sweat Door Heater controls (ASDHC) is small in both territories where there is no proactive DSM program and even in territories with generous utility incentives available.

PAs should consider contracting an experienced implementer or multiple implementers to capture more savings from this proven technology through outreach and proactive marketing.

1.4.4 Evaporator Fan Controls (EFC)

As with the ASDHC measure, the market for Evaporator Fan controls is small in territories where there is no proactive DSM program and even in territories with generous utility incentives available.

PAs should consider contracting an experienced implementer to stimulate the market and capture more savings from this proven technology through outreach and proactive marketing while being sensitive to the existing installers already in the marketplace. It should be noted that this measure is offered both as a stand- alone measure and included in a more sophisticated refrigeration energy management system and may be more cost effective when delivered as part of such a system when multiple measures are bundled into that type of system

1.4.5 Commercial Infrared Heaters

Negative incremental costs were observed for high intensity infrared units across all size ranges due to the lower cost of a typical non-vented unit heater baseline system. That finding, combined with the fact that high intensity infrared heaters are typically unvented and therefore only allowed in certain situations, leads the study authors to recommend discontinuing any incentive programs for high intensity Infrared Heaters.

Since uptake of the low intensity infrared heaters measure is very low in all territories that offer prescriptive rebates, Navigant recommends that PAs consider launching a limited pilot program using proactive marketing and outreach to identify and overcome the barriers to adoption of this technology.

2. Project Design

Like previous phases, ICS4 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 focused on measures offered prescriptively by project sponsors, because such measures are most suitable for this research approach, as well as being of highest interest throughout the region. Figure 2 shows the project design graphically.

Figure 2. Project Design

Source: Navigant Consulting

2.1 Initial Measure Recommendations and Midstream Changes

2.1.1 Measure Selection for the ICS Phase Four Study

The ICS Phase Four considered a total of eight measures, two of which (Commercial Gas Furnaces and Variable Refrigerant Flow Multi-split Heat Pump Systems) were dropped during the course of the study.

All Phase Four measures were commercial and industrial (C&I) sector measures; four were electric measures and four natural gas measures. Table 2 summarizes all measures investigated during ICS4.

Table 2. ICS Phase Four Measures Investigated

Measure	Sector	Fuel	Application	Cost Type
VFD, Variable Displacement and Load/No Load Air Compressors	C&I	Electric	ROB, NC	Incremental
Commercial Kitchen Fryers	C&I	Gas	RET	Incremental
Commercial Kitchen Convection Ovens	C&I	Gas	ROB, NC	Incremental
Refrigeration Anti-Sweat Door Heater Controls	C&I	Electric	RET	Full[3]
Refrigeration Evaporator Fan Controls	C&I	Electric	RET	Full[3]
Commercial Infrared Heaters	C&I	Gas	RET, ROB, NC	Incremental
Commercial Gas Furnaces (dropped)	C&I	Gas	RET, ROB, NC	Incremental
Variable Refrigerant Flow (VRF) Multi-split Heat Pump Systems (dropped)	C&I	Electric	RET, NC	Full and Incremental

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

Navigant presented recommendations for seven energy efficiency measures for the 2014 Incremental Cost Study Phase Four (ICS4) for review and adoption by the Evaluation, Measurement and Verification (EM&V) Forum's Research Subcommittee. Navigant selected these recommended measures from among those measures not selected during the measure screening process for ICS Phase Three, as well as new measure recommendations from NEEP technical experts, study sponsors, and Navigant. We invited input on measures from sponsors and technical experts, and then did an internal screening, taking all qualitative and quantitative comments and rankings into account.

2.1.2 Midstream Changes to Measure Roster

During the Measure Characterization phase of ICS4, Navigant invited internal and NEEP Subject Matter Experts to comment on the initial measure characterizations. Navigant compiled the comments and issues and presented them to the Subcommittee in August of 2014. As a result of that meeting, the following changes were made to the scope of ICS4:

- Out of concern for budgetary limitations, and because it was the least commonly installed and rebated of the three proposed types of air compressors, retrofit Variable Displacement Air Compressors were removed from the air compressor measure list. Only factory-installed VFD and Load/No Load Air Compressors were investigated.

- VRF Multi-split Heat Pump Systems were included in ICS4 because of Program Administrator interest in this emerging measure, although previous experience with these systems in incentive programs was limited. Program Administrators were interested in cost research on this measure because they were not certain the existing incentives were appropriate to a technology not well known to customers and vendors. During the characterization period, the building types to be

[3] Evaporator Fan Controls and Anti-Sweat Door Heater Controls have no "efficient" alternative. Cost scenario is retrofit only, and full equipment and labor costs are included.

studied were narrowed to the three most common, (Office Buildings, Schools and Multifamily), and the possible baseline equipment types narrowed to two (Water Source Heat Pump (WSHP) and 4-pipe chiller/boiler systems). The ICS4 team then moved on to the Data Collection phase of the study, during which other issues with respect to the VRF Multi-split Heat Pump Systems and Commercial Furnaces measures were discovered.

Finally, the team learned that MassSave, the only NEEP member Program Administrator that was offering prescriptive incentives for VRF systems, was likely to remove the measure from its prescriptive roster for the 2015 Program Year, citing low uptake, the large variety of baselines, installation scenarios, system architectures and other variables as reasons why there was no way to establish a prescriptive incentive that fit every scenario.

- For Commercial Furnaces, although prescriptive incentives were offered by multiple program administrators, Navigant discovered during the data collection phase that this measure was not being installed in any significant numbers anywhere in the Northeast or Mid-Atlantic states. The team could find *no* examples of a commercial-sized (>225 kBtu/h) ducted furnace installation with thermal efficiencies close to the proposed rebate levels. Internet searches yielded no qualifying models of *ducted* commercial-sized furnaces.

Navigant reviewed these findings with the NEEP team, and the consensus was to drop both measures from the ICS4 study. Because it appeared that this would free up enough of the remaining project budget to add another measure to the study, the team proposed three possible measures, which the NEEP team reviewed and submitted to the Research Subcommittee. The measure candidates included:

- Compressed Air Refrigerated Dryers
- Commercial Refrigeration Evaporator Fan Controls
- ENERGY STAR *Electric* Commercial Convection Ovens and Fryers

The feedback from the Subcommittee was strongly in favor of the Evaporator Fan Controls measure. With the above changes, the final ICS4 Measure Roster was as shown in Table 3, below:

Table 3. ISC4 Final Measure Roster

Measure	Fuel	Sector
Factory-Installed VFD, and Load/No Load Air Compressors	Electric	C/I
Infrared Heaters	Gas	C/I
Commercial Kitchen Fryers	Gas	C/I
Commercial Kitchen Convection Ovens	Gas	C/I
Refrigeration Anti-Sweat Door Heater Controls	Electric	C/I
Refrigeration Evaporator Fan Controls	Electric	C/I

3. ICS Research Methodology and Process: Continuity and Changes

Although the overall approach to data collection and analysis for the ICS4 did not change, Navigant made some modifications to the study design and process. The two primary differences were as follows:

» **Deferred measure list from ICS3 scored matrix of potential measures was used as a starting point.** For ICS3, a 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 4. Many of the measures considered for ICS4 were the highest scoring measures that were not investigated in ICS3 or were otherwise disqualified at the time.

Table 4. Measure Screening Criteria

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

» **Data collection protocol was updated.** Following the same process as ICS3, ICS4 data collection was conducted in a two-stage process. In the first stage, Navigant conducted in-depth paid interviews with at least two installers, manufacturers and/or industry experts per measure. These in-depth interviews covered the following topics:

- Confirming measure baseline technology and costs.
- Further defining the efficient measure boundaries (e.g., is ancillary equipment essential to the "typical"[4] installation?).
- Defining the typical installation and in some cases a more complex installation (e.g., evaporator fan controls [EFC]).
- 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.

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. In addition, where needed, Navigant also made use of internet searches for equipment costs and consulted a study conducted for the California Public Utility Commission by Itron, Inc.[5] Navigant attempted to gain a broad representation of measures from program administrators. However, Program administrators differed in the ICS4 measures they offered on

[4] "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.

[5] 2010-2012 WO017 Ex Ante Measure Cost Study Draft Report, submitted to the California Public Utilities Commission by Itron, Inc., February 28, 2014. Results from this study, which used a different methodology were employed as reality checks on three ICS4 measures, but were not used as direct inputs for analysis.

a prescriptive basis. Some PAs offered measures only on a custom basis. We also found instances where PAs offered measures on a prescriptive basis but had no actual rebate applications over the past year. Finally, not all data points we collected were usable. In most such cases, data points were not usable because they lacked sufficient detail in either measure description (make/model), or multiple measure project costs were aggregated. Table 5 shows the number of usable data points by measure and by program administrator.

Table 5. Data Points by Measure and Source

Program Administrator	VFD and Load/No Load Air Compressors		Commercial Kitchen Fryers		Commercial Kitchen Convection Ovens		Refrigeration Anti-Sweat Door Heater Controls		Refrigeration Evaporator Fan Controls		Commercial Infrared Heaters	
• = prescriptive ♦ = custom	Data Points	Rebates Offered?	Data Points	Rebates Offered?	Data Points	Rebates Offered?	Data Points	Rebates Offered?	Data Points	Rebates Offered?	Data Points	Rebates Offered?
BGE	3	♦	8	•				•		•		
Berkshire Gas				•		•						•
Con Ed		♦					164	•	1822	•		•
Conn. Light & Power/ Yankee Gas		•		•		•						•
Columbia Gas			25	•	23	•					11	•
National Grid	102	•	9	•	9	•	30	•	6	•		
Eversource (NSTAR)		•		•		•	26	•		♦		
Groton Utilities								♦		♦		
NU												
NYSEG		♦										♦
NYSERDA				•		•		•				•
PSEG LI		•								•		
PEPCO	5	•		•		•	8	•	8	•		
VEIC (EVT and DCSEU)	11	•				•	22	•		•		
Burlington (VT) Electric Dept.		•								•		
Unitil		•		•		•		♦		♦		
United Illuminating (CNG, SCNG)				•		•						
Liberty Utilities								♦		♦		
PSNH								♦		♦		
Efficiency Maine								•		•		
Cape Light Compact		•										
Internet search	24		113		179				4		250	
TOTALS*	**145**		**155**		**211**		**250**		**1840**		**261**	

	VFD and Load/No Load Air Compressors	Commercial Kitchen Fryers	Commercial Kitchen Convection Ovens	Refrigeration Anti-Sweat Door Heater Controls	Refrigeration Evaporator Fan Controls	Commercial Infrared Heaters
CPUC/Itron Study* data points		123	126		5	
Interview Candidates	**11**	**44**	**45**	**24**	**9**	**28**

*Data from the CPUC/Itron study not used for analysis, only for comparison to this study's results. The CPUC/Itron data points are not included in the totals.

Internet data

Internet data have been a part of data collection from ICS Phase 1. Internet data are most useful for distinct national product markets and for commodity measures such as lighting sensors. Internet sources do not provide installation costs, which we were able to obtain from interviews with installers (commercial infrared heaters and VFD compressors) and in some cases, manufacturers, in specialized markets such as commercial kitchen equipment.

California PUC Itron Report[6]

In 2010, the California Public Utility Commission ("CPUC") commissioned a cost study carried out by Itron, Inc., cited above, which is referred to in this report as the CPUC/Itron study. While the NEEP ICS project has worked from the bottom up – interviews with installers, research at the retail offerings level and specific focus on participating Sponsor data, the CPUC/Itron study worked from the top of markets downward, focusing to a large extent on measures that operate in national markets. Because Itron focused on measures with national markets, only a few measures studied by Itron have overlapped with the ICS. Additionally, the cost analysis methodology appeared to differ from the ICS but Navigant did not have access to the detailed analysis methodology; therefore direct comparisons between the ICS and CPUC/Itron results could not be readily determined. As a consequence of these differences, results from the CPUC/Itron study were employed as reality checks on three ICS4 measures where the CPUC/Itron and ICS4 studies did overlap but were not directly employed in the analyses. Despite the differences noted, Navigant found both studies produced reasonably comparable costs on measures studied in common.

Cost Factors

Using R.S. Means updated market-specific equipment and labor cost factors for 2015 costs updated for inflation, Navigant generated preliminary equipment 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 concerns, where appropriate. Peer reviewers included program administrator staff, implementation contractors, and NEEP consultants, who also helped Navigant present costs in a manner most useful to program administrators, planners, and evaluators.

[6] CPUC/Itron Cost Study, 2014

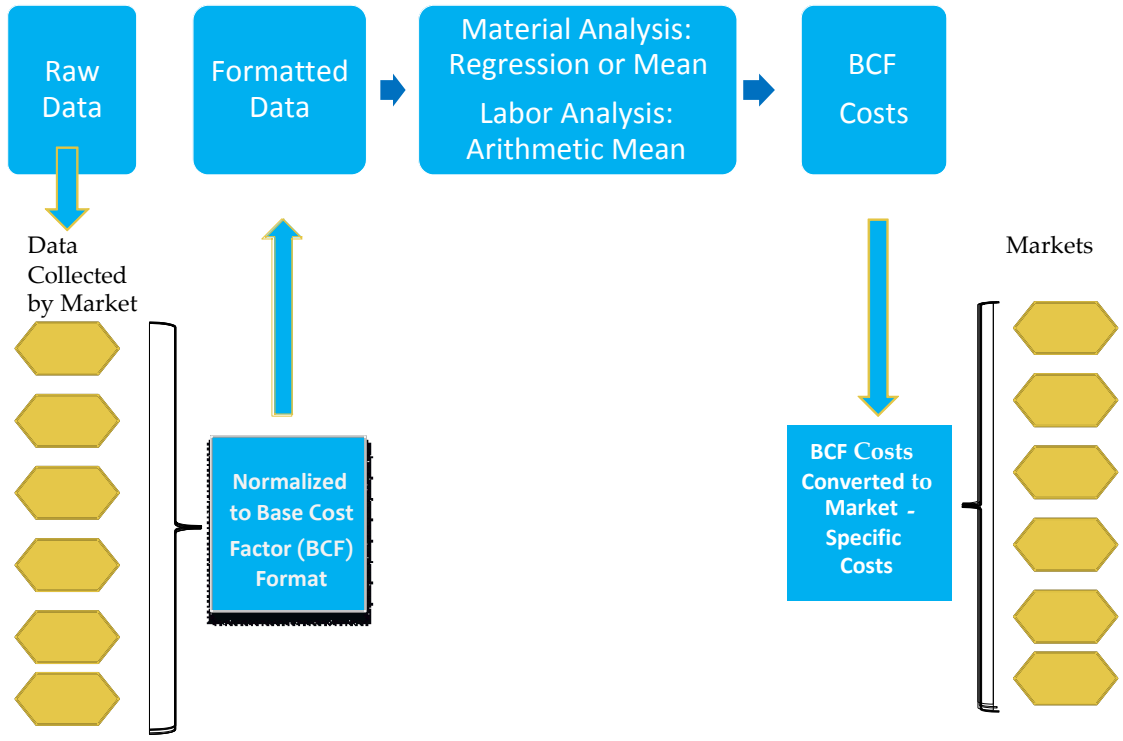
4. Data Analysis and Quality Control

4.1 Data Analysis and Quality Control

Data Analysis and Quality Control for ICS Phase Four did not differ substantively from Phases One, Two and Three. Data collected from program sponsors, installers, and other sources were placed on a single analytic platform. The research team achieved this using R.S. Means equipment and labor cost factors to adjust data collected in each market. As can be seen in Figure 1 on page 5, equipment cost adjustments vary only over a small range, from 0.99 to 1.03. Labor costs adjustments, however, are much more variable, ranging from 0.84 in northern New England to 1.55 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 Base Cost Factor (BCF), using regression analysis or arithmetic means, as most appropriate. The BCF was then adjusted for each market, using adjustment factors for equipment. For Retrofit scenarios or ROB and NC where the efficient measure also requires incremental labor costs, the BCF labor costs were also adjusted for each market.

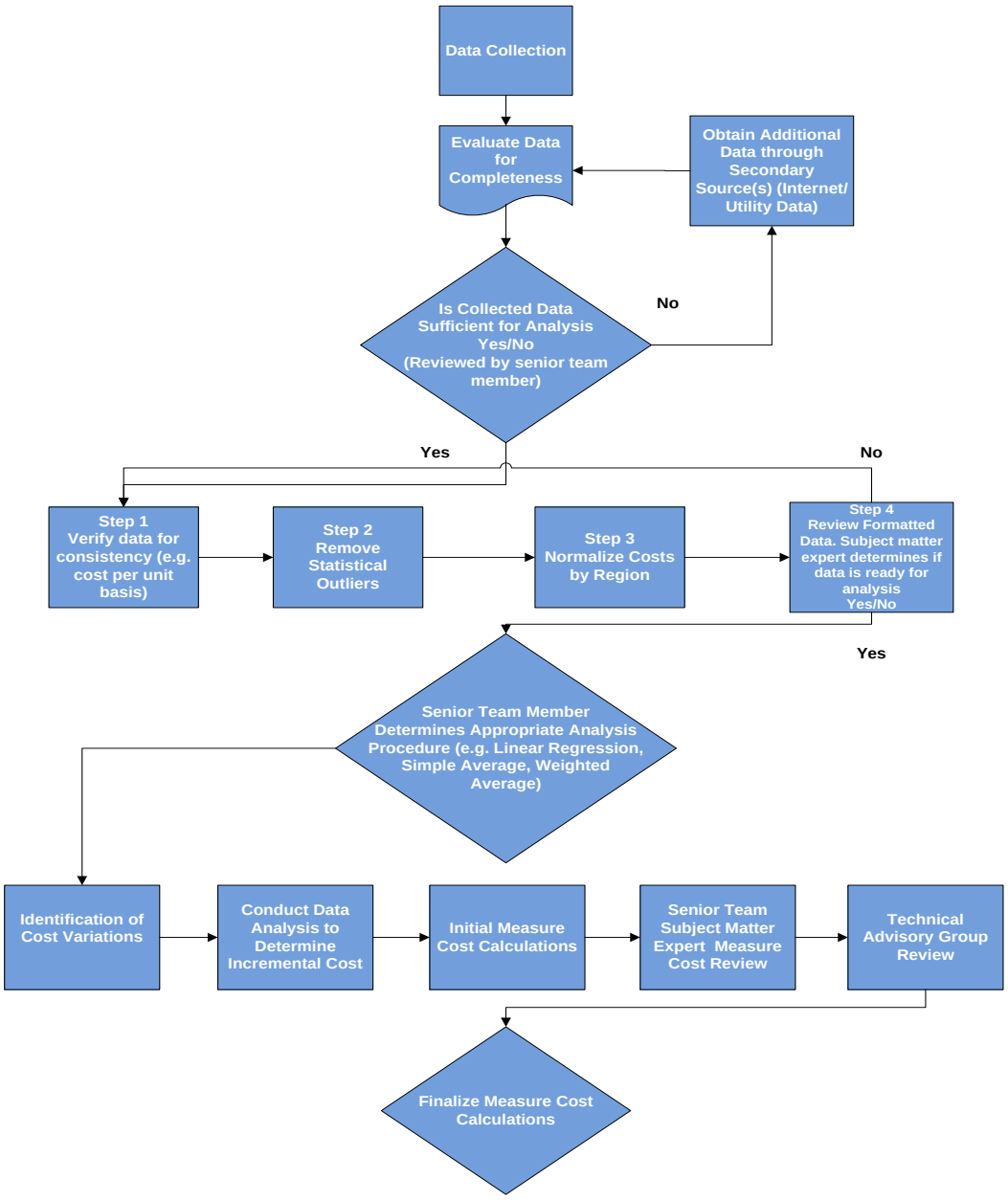
Figure 3. Cost Analysis Process Including Formatting, Base Cost Factor and Final Cost Determination for Each Market – Applies to both Baseline and Qualifying Equipment



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

The ICS Quality Control process is demonstrated in Figure 4. Once material and labor costs were collected for a given measure, 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 from additional sources. If the data collected was sufficient for analysis, the team would move on to the Final Data Review Phase.

Figure 4. ICS4 Quality Control Process



Source: Navigant Consulting, Inc. 2014

The Final Data Review 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 subject matter experts 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, before the measure proceeded to the Analysis Phase.

The Analysis Phase 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 appropriate approach. 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.

4.2 Treatment of Outliers in the Analyses

One or more of three different methodologies for determining outliers were used to screen the data for each measure analysis, depending on the characteristics of the particular data set, and the type of analysis used – arithmetic mean or linear regression. Those three methodologies are:

- Removing data points a certain number of standard deviations on either side of the arithmetic mean. The most commonly used test is two standard deviations either side of the mean, but in the case of the Evaporator Fan Control measure, 1.5 standard deviations was chosen since two standard deviations would not have identified any outliers.
- Removing the data in the top and bottom deciles (10 percentiles) of the data distribution. This method insures that at least one data point on either end of the data range will be removed.
- For regression analyses, a third method may be used, namely removing the data with the largest residuals either side of the best fit trend line.

Table 6. Outlier Methodology by Measure

Measure	Standard Deviation Method	Decile Method	Residuals Method
Air Compressors			•
Commercial Fryers	•		
Commercial Convection Ovens	•		
Anti-Sweat Door Heater Controls	•		
Evaporator Fan Controls	•	•	
Infrared Heaters			•

5. Measure Characterizations and Costs

5.1 Introduction

This section includes ICS4 measure characterizations and results of the analysis in the form of Base Cost Factors. The Base Cost Factors can be adjusted by market, as noted in the text box below, to be used in a program administrator service territory as an input to a benefit cost analysis or in designing local program incentives, for example. 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 Subject Matter Experts (SMEs) and modified as appropriate.

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 given market. Equipment costs do not vary greatly from market to market but installation costs may 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 http://www.neep.org/initiatives/emv-forum.

Table 7. VFD Air Compressors Characterization

Tables 7 through 19 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). Replace on Burnout is the case where a piece of equipment would need to be purchased anyway and the program is paying the incremental cost (difference) between what would normally be installed and the cost of the high efficiency version of that same equipment Similarly, New Construction is the case where a more efficient alternative exists for equipment that was not previously in place; thus incremental costs are also examined. Full costs are provided for Retrofit (RET) scenarios where the program pays for the full or partial cost of replacing a fully functioning piece of equipment.

5.2 Life Cycle Cost Considerations

The Incremental Cost Study focused upon the equipment, materials and installation costs of energy efficiency measures. These incremental measure costs are good guides for setting incentive levels in energy efficiency programs. Typical benefit cost calculations do not consider some life-cycle implications, such as comparative operations and maintenance (O&M) costs, early replacement scenarios where the remaining useful life of the measure is not considered, or greatly differing expected measure lives, which are relevant to some measures. In previous phases of the NEEP ICS, Navigant has taken these life cycle disparities into account when reporting final measure costs. 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. However none of the ICS4 measures required such adjustment.

5.3 Measure Characterizations, Costs and Other Important Considerations Derived from Data Collection and Analysis

This section of the ICS4 report describes the specific characteristics of each Phase Four measure, reports the Base Cost Factors for each measure and also discusses important findings about individual measures. As applicable to each measure, these findings may include:

- Baselines;
- Applications;
- Information Source(s);
- Impacts on ICS4 Research;
- Market Issues;
- Other Issues;
- Resolution of Concerns Found; and/or
- Program Design Implications.

5.3.1 VFD Air Compressors – Electric

Table 7. VFD Air Compressors Characterization

Efficient Measure Description	New VFD-equipped Air Compressor
Baseline Description	Modulating or Load/No-Load Air Compressor **without** VFD
Measure Scenario(s)	NC, ROB
Measure Specifications	Single Compressor Systems Only Efficiency Vermont: Rotary Screw or Rotary Vane only MassSave: Maximum Discharge Pressure: 145 PSI MassSave: Min. storage requirement is 2 gal. per acfm compressor capacity MassSave: Oil-flooded rotary screw only MassSave: must have a min. 3% impedance series reactor in AC power input
Sizes	Generally 10 to 100 HP; MassSave: 15 to 75 HP
Distinguishing Features	VFD must be factory-installed, not retrofitted
Installation Scenarios	New VFD Air Compressor installed in New Construction, or replacement compressor in an existing single air compressor system
Sources	Mass Save, Baltimore Gas & Electric, Con Edison, Efficiency Vermont, Energize CT, DC Sustainable Energy Utility, Cape Light Compact , Liberty Utilities, and PSEG Long Island

Table 8. VFD Air Compressors Base Cost Factor v. Baseline (Modulating and Load/No Load)

Size Category (horsepower)	Incremental Base Cost Factor - BCF ($/Unit)	
	VFD ($)	VFD ($/HP)
15	$5,585.09	$372.34
20	$5,312.06	$265.60
25	$5,039.04	$201.56
30	$4,766.01	$158.87
40	$4,219.95	$105.50
50	$3,673.90	$73.48
60	$3,127.84	$52.13
75	$2,308.76	$30.78

Findings Summary

A key finding of the air compressor study is that, especially for lower horsepower compressors, the cost of a baseline (modulating) air compressor is nearly the same as a Load/No Load Air Compressor of the same horsepower. This finding is discussed in more detail in the Analysis workbook for the Air Compressor measure. Table 7 uses this finding as its premise, and presents the incremental cost of VFD Air Compressors vs. the aggregated cost of baseline and Load/No Load Air Compressors for eight

commercially available horsepower levels from 15 to 75 horsepower. The incremental cost results in Table 8 are presented as the incremental cost per compressor in column two, and the incremental cost per horsepower in column three. The cost per horsepower results are presented to allow Program Administrators to estimate the cost of intermediate horsepower compressors.

Baseline Issues

- Based on PA input, the initial baseline level for this measure was considered to be an Air Compressor without Load/No-Load controls or a Variable Frequency Drive, which is most commonly a modulating air compressor. However, after conducting four interviews with sales representatives, it became clear that Load/No-Load[7] compressors are now considered the baseline for this measure. The cost data collected for this study confirms this observation in the lower horsepower range. Navigant compared the costs for Load/No-Load compressors and modulating compressors in the raw data, and determined that in the horsepower range for which baseline compressor cost data was available, there was little to no difference in costs between the two groups. As a result, Navigant performed a new analysis in which baseline compressor cost data was combined with Load/No-Load compressor cost data and the incremental cost from the new baseline to Variable Frequency Drive compressors was determined.

Applications

- Based on the PA invoice data, it appears that Air Compressors are used in a variety of industrial and commercial applications, ranging from manufacturing facilities to food production facilities.

Information source(s)

- Qualitative information was gathered from manufacturer website literature in order to understand various characteristics of Variable Frequency Drive Air Compressors, such as size, weight, and electrical specifications. Sales representative interviews also produced qualitative information on how customers select Air Compressors and ancillary materials, which ancillary materials are necessary, which are optional, and why labor costs vary between installations.
- Quantitative information was gathered from invoices provided by National Grid, PEPCO, BG&E, and Efficiency Vermont, as well as through four sales representative interviews.

Impact on ICS4 Research

- Due to the baseline issues discussed above, Navigant conducted multiple analyses before presenting the results summary shown in this report that present the incremental cost for Variable Frequency Drive Air Compressors compared to the modulating and load/no load baseline on a per machine and per horsepower basis.

Market Issues

- Based on interview results and data gathering, it was determined that baseline modulating air compressors are not being sold in significant quantities, which indicates that Load/No-Load Air Compressors can be considered as baseline equipment in the current market. The difference in cost between modulating and Load/No Load air compressors below 40 HP is small enough that most purchasers will opt for the more efficient Load/No Load machines without an additional

[7] Or compressor with both load/no-load and modulating controls

financial incentive. This should be taken into account by PAs when establishing or redesigning air compressor rebate programs.

- Based on interviews with subject matter experts and manufacturers, this study found that most manufacturers produce only limited sizes of air ends (the mechanical assembly used to compress air) for a given horsepower range. The output of the compressor is then varied by selecting an appropriate motor size for a given air end. When the output required exceeds the capability of the air end using the largest applicable horsepower, manufacturers will jump to the next size air end which can result in a non-linear cost jump. To simplify the analysis and results, these non-linearities were ignored, the assumption being that the location on the cost curve for these anomalies and the size of the jump would vary across manufacturers and average out in the results.

- The study also revealed that some manufacturers are building "dual control" compressors which can switch from modulating to Load/No Load operation using a selector switch on the control panel. This category of air compressors were not covered in this study due to lack of resources.

- For one major air compressor rebate program, a minimum volume is specified for a storage tank which must be purchased in conjunction with the Air Compressor in order to qualify for a utility rebate. For Variable Frequency Drive rebates, this was two gallons of storage per ACFM of compressor capacity, and for Load/No-Load rebates, this was four gallons of storage per ACFM of compressor capacity. As a result, the cost of storage for a Load/No-Load Air Compressor could be greater than that for a Variable Frequency Drive Air Compressor or a baseline air compressor of the same capacity. To the extent that adequate storage capacity is required to realize the full energy benefit of the Load/No Load air compressor, PAs may need to continue to incentivize the purchase of these machines to offset the added cost of storage tanks. However, the analysis of this ancillary equipment was beyond the scope of this study.

Other Concerns

- Several interviewees noted that customers who purchase Variable Frequency Drive Air Compressors are more likely to purchase efficient ancillary equipment (such as Low-Pressure Drop Filters and Cycling Refrigerated Air Dryers) than are customers who purchase baseline air compressors. This finding suggests that PAs should take these customer purchase patterns into account in designing energy efficiency programs to leverage limited incentive dollars and maximize energy savings.

Resolution of Concerns Found

- The conundrum of Load/No-Load compressor costs being barely distinguishable from baseline modulating compressor costs at low horsepower ratings was resolved by considering a baseline case in which Load/No-Load and modulating compressors were aggregated. This re-definition of the baseline case was validated by in-depth interviews in which sales representatives from various Air Compressor manufacturers noted that they rarely sell equipment less efficient than Load/No-Load Air Compressors, and hence consider Load/No-Load to be the new baseline.

Program Design Implications

- Contractor responses about customer purchase patterns (i.e. buyers of efficient equipment tend to buy efficient ancillary equipment, while buyers of standard efficiency equipment do not),

suggest that PAs should consider incentives that capture both compressors and ancillary equipment to drive the market toward increased purchase of efficient compressor systems, rather than simply focusing on the efficiency of the compressor itself.

- As discussed above, to the extent that adequate storage capacity is required to realize the full energy benefit of the Load/No Load air compressors, PAs may need to continue to incentivize the purchase of these machines to offset the added cost of storage.

-

5.3.2 Commercial Kitchen Fryers – Natural Gas

Table 9. Commercial Kitchen Fryers Characterization

Efficient Measure Description	**ENERGY STAR® Commercial Natural Gas Fryers**		
Baseline Description	Standard Commercial Natural Gas Fryer		
Measure Scenario(s)	NC, ROB		
Baseline Efficiency Levels and Specifications	Existing or new gas fryer with standard 35% cooking efficiency		
Measure Level Description	ENERGY STAR® qualified commercial fryers, which save energy with shorter cook times and higher production rates through advanced burner and heat exchanger designs		
Measure Efficiency Levels and Specifications	ENERGY STAR Criteria: Gas		
	Fryer Type	Idle Rate (Btu/h)	Cooking Efficiency (%)
	Standard Open Deep	≤ 9,000	≥ 50%
	Large Vat Open Deep	≤ 12,000	
Sizes	Per fryer; Fryers can have multiple vats, and can differ in shortening capacity		
Distinguishing Features	ENERGY STAR qualified; meeting the criteria described in the "Measure Efficiency Levels and Specifications," above		
Installation Scenarios	Commercial kitchens – New Construction or ROB		
Sources	Massachusetts TRM, Mass Save, Rhode Island TRM, Delaware TRM, Energize CT, Baltimore Gas and Electric, DC Sustainable Energy Utility, Food Service Technology Center, ENERGY STAR website, Illinois TRM, and Indiana TRM		
Comments	Equipment cost generally plays a more significant role in commercial fryer purchasing decisions than the operating cost. Cooking energy efficiency is the ratio of energy added to the food and the total energy supplied to the oven during cooking.		

Table 10. Commercial Kitchen Fryers Base Cost Factor v. Baseline

Equipment Description	Incremental Base Cost Factor - BCF ($/Unit)		
	Incremental Cost ($/Unit)	Incremental Cost ($/lb of Shortening Capacity)	Incremental Cost ($/kBtu)
Commercial Kitchen Fryer	$2,580.03	$34.12	$24.79

Findings Summary

The primary finding of this research was that though there is an incremental cost between non-qualifying (baseline) and ENERGY STAR compliant units, the market share of non-qualifying (baseline) models in the market place is diminishing. The ENERGY STAR qualifying criteria is seen as a low threshold for manufacturers to meet, which has resulted in a market saturated with ENERGY STAR rated fryers and diminished importance of the ENERGY STAR label as a distinguishing factor and possibly diminished need for paying incentives for ENERGY STAR units.

Baseline Issues:

- ENERGY STAR qualified commercial fryers save energy with shorter cook times and high production rates through advanced burner and heat exchanger designs. ENERGY STAR qualification is based on a unit's idle rate and cooking efficiency. Cooking efficiency is the ratio of energy added to food to the total energy supplied to the fryer during cooking.
- There is little that distinguishes ENERGY STAR rated units from non-ENERGY STAR rated units other than energy efficiency. This incremental cost analysis was originally designed to normalize equipment costs based on their cooking efficiency. However, this key energy performance criterion is not typically published by manufacturers/retailers and proved difficult to identify for non-qualifying units.

Market Issues

- The major issue concerning the market for commercial kitchen gas fryers is the influence of the secondary or used market. Customers and operators of commercial kitchens, such as independently-owned restaurants, schools, and small retail establishments typically do not have the up-front equity to invest in new equipment. As a result, the secondary market for used equipment is the primary source for equipment for a large portion of commercial kitchens. The size and influence of this secondary market complicates pricing and creates incremental cost analysis issues as program rebates target new equipment rather than used equipment.
- For new equipment, cooking efficiency influences the cost of equipment but the major drivers of price are the equipment's reliability, durability, and quality of materials.
- Restaurant franchises and fast food chains make up a significant portion of commercial kitchen equipment purchases. One industry expert postulated they represented 50% of the market. Restaurant franchises and fast food chains are also frequent participants in energy efficiency programs, installing and receiving rebates for qualifying units, a fact that is supported by NEEP PA data and interviews with industry experts. However, the suppliers to these restaurants refused to participate in the study, and even after multiple guarantees of confidentiality, would not share their cost data, leaving a major segment of market data out of the study.

- Through our communication with vendors and industry experts, Navigant found that the Manufacturer's Suggested Retail Price (MSRP) was rarely the price paid in the marketplace for retail sale. The MSRP is a mechanism utilized by manufacturer's to standardize prices among locations in a specific region. Every avenue Navigant researched suggested the industry standard was to not adhere to MSRPs, but rather price equipment below, and in most cases, substantially below, the MSRP. As a result, the MSRP is rarely the price paid in the commercial fryer retail market place.
- As a test of the validity of the study results, Navigant compared the results of this incremental cost study with those of a similar cost study performed by Itron for the CPUC in 2014. Both studies focused on new equipment rather than the used secondary market for both the baseline and efficient conditions. On a per unit basis, the results of the Navigant/NEEP study came within 1% of the results reported in the CPUC study.

Other Issues

- Commercial kitchen equipment is typically purchased in a replace-on-burnout scenario due to customers' limited funds and a belief that it is not cost effective to replace a functioning unit solely on the basis of energy savings. This intensifies the impact energy efficiency rebate programs can have in encouraging early replacement. This finding applies primarily to establishments that are not national chains. The practices of those companies may vary substantially from the findings in this study.

Program Design Implications

- Navigant's communication with one manufacturer as well as an industry expert revealed that the number of non-qualifying models in the market place is diminishing. The ENERGY STAR qualifying criteria is seen as a low threshold for manufacturers to meet, which has resulted in a market saturated with ENERGY STAR rated fryers and diminished importance of the ENERGY STAR label as a distinguishing factor. In some cases, manufacturers are discontinuing the production of non-qualifying units altogether. With limited incremental savings and an apparently transforming/transformed market, providing incentives for this measure may not be highly cost effective without increases in ENERGY STAR standards or the addition of higher tier standards to further stimulate the market for efficient equipment.

5.3.3 Commercial Kitchen Convection Ovens – Natural Gas

Table 11. Commercial Kitchen Convection Ovens Characterization

Efficient Measure Description	**ENERGY STAR® Commercial Gas Convection Ovens**		
Baseline Description	Standard Commercial Convection Oven		
Measure Scenario(s)	NC, ROB		
Baseline Efficiency Levels and Specifications	Existing or new gas convection oven with standard 30% cooking efficiency		
Measure Level Description	ENERGY STAR® qualified commercial convection ovens, which save energy during preheat, cooking, and idle times due to improved cooking efficiency, and lower preheat and idle energy rates		
Measure Efficiency Levels and Specifications	ENERGY STAR® Criteria: Gas		
	Oven Capacity	Idle Rate (Btu/h)	Cooking Efficiency (%)
	Full-Size	≤ 12,000 Btu/h	≥ 46%
Sizes	Per full size oven. The size of the oven depends on whether it can accept standard full-size (18" x 26" x 1") or half-size (18" x 13" x 1") sheet pans. Ovens come in single, double or quadruple stacks.		
Distinguishing Features of Efficient Measure	ENERGY STAR® qualified; meeting the criteria described in the "Measure Efficiency Levels and Specifications," above		
Installation Scenarios	Commercial kitchens - New Construction or ROB		
Sources	Massachusetts TRM, Mass Save, Rhode Island TRM, Delaware TRM, Energize CT, Baltimore Gas and Electric, DC Sustainable Energy Utility, Food Service Technology Center, ENERY STAR website, Illinois TRM, and Indiana TRM		
Comments	Cooking energy efficiency is the ratio of energy added to the food and the total energy supplied to the oven during cooking		

Table 12. Commercial Kitchen Convection Ovens Base Cost Factor v. Baseline

Equipment Description	Incremental Base Cost Factor - BCF ($/Oven Cavity)
Commercial Gas Convection Oven	-$1,790.61

Findings Summary

The incremental cost for this measure is noteworthy because it is negative. Some of the marketplace circumstances resemble those detailed in section 5.3.2., above, regarding commercial fryers:

- A substantial used equipment market.
- Restaurant franchises and fast food chains constitute up to 50% of the market according to one industry expert. These companies substantially participate in energy efficiency incentive programs, as seen in data analyzed for the study. However, we were unable to find any such companies that would participate in the study, despite assurances of confidentiality.
- Non-ENERGY STAR ovens appear to be rapidly declining in the marketplace and some manufacturers now provide only ENERGY STAR compliant units.
- The Navigant study yielded a negative incremental cost estimate for Commercial Convection Ovens, which closely mirrored the results of a similar cost study performed by Itron for the CPUC in 2014 for this measure. A negative incremental cost means the baseline equipment is more expensive *on average* than the efficient alternative. On a per unit basis, Navigant reported a larger negative disparity between the baseline and efficient conditions than the CPUC study did. Both studies focused on new equipment rather than the used secondary market for both the baseline and efficient conditions.
- Although the market is moving toward the ENERGY STAR compliant units, the more durable, more reliable high-end non-qualifying units with top-quality materials and controls are still in high demand, and the production of these units has continued unabated. Thus most of the new, non-qualifying units in the market today are high-end, high-priced alternatives to ENERGY STAR rated units, resulting in a negative average incremental cost.

Program Design Implications

- As with commercial fryers, early replacement strategies may be the most cost-effective for these measures. There may also be value in stressing energy efficiency as a feature to the higher end units through some kind of social marketing campaign. For reasons that are not clear, unlike appliances such as central air conditioners or refrigerators, the highest end commercial units do not stress energy efficiency but rather extra features and high-end materials. This may again reflect the relatively low efficiency improvement between current ENERGY STAR and baseline units.

5.3.4 Refrigeration Anti-Sweat Door Heater Controls - Electric

Table 13. Refrigeration Anti-Sweat Door Heater Controls Characterization

Efficient Measure Description	Anti-Sweat Door Heater Controls installed on reach-in cooler/freezer doors to turn off door heaters when not necessary to prevent condensation.
Baseline Description	Reach-in Cooler or Freezer Doors with uncontrolled Anti-Sweat Door Heaters operating continuously
Measure Scenario(s)	RET only (This equipment is baseline in new construction per IECC 2015)
Baseline Efficiency and Specifications	Continuous, uncontrolled Door Heater operation
Measure Level Description	Anti-Sweat Door Heater Controls allow for 'on/off'* operation of heaters installed on refrigerated cooler/freezer doors. Without control these heaters are assumed to operate continuously. Controlling anti-sweat door heaters also reduces building and cooler/freezer cooling load. *Pulse-Width Modulation (rather than on/off operation) may be used by certain controllers to reduce thermal stress on heating elements.
Measure Efficiency Levels and Specifications	Deemed savings from reduced heater run-time and reduced building and display case cooling load. Based on applicable TRMs, annual runtime is typically reduced to approximately 4,700 hrs for Freezers and 2,270 hrs for Coolers. Depending on control strategy, climate, and setting parameters, runtime may be reduced significantly further.
Sizes	Per Door (Standard Unit), Per Circuit (ME), Per Linear Ft. Case (NGRID MA/RI), Per kWh Saved (Groton Utilities, CT)
Distinguishing Features Installation Scenarios	Typical Building Type: Grocery Store, Convenience Store **Two control approaches:** (1) Door heaters are controlled based on the relative humidity of the air outside of the controlled display case. (2) Door heaters are controlled based on sensors that measure door glass conductivity, and activate heaters when condensation is detected **Incentive Approaches:** **VT (EVT):** Must be a humidity based control. **NH (PSNH, Unitil, Liberty):** No Prescriptive Incentive Offered; Custom only. **ME (Efficiency Maine):** No Control Approach Specified, Incentive offered per circuit. **MA (National Grid Only):** No Control Approach Specified **RI (National Grid Only):** No Control Approach Specified **CT (Groton Utilities):** No Control Approach Specified, Prescriptive incentive offered at $0.14 per kWh saved **MD (BGE):** Humidity based control, other strategies may qualify. **D.C. (D.C. SEU):** Must be Humidity Based
Sources	NY TRM, Efficiency Maine TRM, Massachusetts TRM

Table 14. Refrigeration Anti-Sweat Door Heater Control Base Cost Factor

Unit	Base Cost Factor ($/Unit)
Door Heater Controller	$1,266.11
Cooler Door	$126.61
Freezer Door	$281.36

Note: This measure includes Full Equipment and Labor Costs.

Findings Summary

The primary finding of this study is that the market for Anti-Sweat Door Heater controls is small in territories where there is no proactive DSM program, even in territories with generous utility incentives available. PAs should consider contracting an experienced implementer to capture more savings from this proven technology through outreach and proactive marketing.

Baseline Issues

- The baseline for the Anti-Sweat Door Heater Controls (ASDHC) measure is uncontrolled door heaters at no cost, so our study reports the full installed cost of the ASDHC. This is a retrofit-only measure due to its inclusion as baseline in the 2015 IECC commercial code.

Applications

- The baseline condition for door heaters is continuous operation (8,760 hours/year runtime), and ASDH controls are used to limit the runtime of heaters on freezer and cooler doors to only when these heaters are needed to prevent door condensation.

Information Source(s)

- Program tracking data sourced from New York City and other Program Administrator regions included only singular pricing per unit indicating a negotiated contract price for an approved installer, which was confirmed by the respective PAs. To reduce the undue influence of these negotiated prices, the data set from each region was distilled down to one data point using average material and labor costs. The cost was also discounted by 20% as an estimate of the marketing and outreach budget included in those contract prices.

Market Issues

- In markets where contract pricing dominated a particular region, Navigant did not have access to the proprietary pricing structure in order to disaggregate the cost of the ASDHC installation from other refrigeration measures often installed as a package. For these markets we were able to acquire information from an interview that included data such as average quantity of doors per circuit, installation time, and sometimes an estimate of control hardware cost.
- In other markets (e.g. VT and NH) we interviewed a single contractor that did not want to share the make/model information of their control equipment as they felt this information was proprietary.
- Generally speaking, there was a noticeable perception among contractors interviewed and interview candidates that they potentially faced a business risk in providing us with specific or disaggregated cost information, despite attempts to ensure confidentiality, explain the public benefit of providing this information, and offers of financial incentives.

- A further challenge was trying to utilize cost data for controls that are capable of functionality beyond simply managing door heater circuits. These controls may be significantly more expensive than standard purpose-built ASDH controls, and there is no accurate way to disaggregate the cost of the ASDH control component. Because of the inherent inaccuracy, it was decided that these data points should be excluded from the analysis[8].

Resolution of Concerns Found

While we were diligent in mining as much information we could from willing contractors, the internet, and cold-calls, we also used assumed information based on a combination of data collected in the interviews (e.g. doors per circuit, labor times) and regional cost and labor information provided by RS Means to fill in some gaps in our data.

Program Design Implications

- Installation costs and energy savings from ASDH controls are significantly greater for freezers than refrigerators, while program incentives for all but one NEEP utility (Groton, CT) are the same for freezers and refrigerators. This finding suggests that effectively penetrating this market further may require either a custom approach or a more nuanced prescriptive measure approach, differentiating among equipment types.

[8] These data points were excluded. The $1,200 result includes only single-purpose controls. Unit is different for each line, defined in first column, i.e. per controller, per cooler door or per freezer door.

5.3.5 Refrigeration Evaporator Fan Controls – Electric

Table 15. Refrigeration Evaporator Fan Controls Characterization

Efficient Measure Description	Refrigeration Evaporator Fan Controls installed in walk-in coolers or freezers to turn off or reduce the speed of evaporator fans when the compressor is not running.
Baseline Description	Uncontrolled evaporator fans running continuously at full speed
Measure Scenario(s)	Retrofit (RET) only
Baseline Efficiency and Specifications	8,760 Hours, continuous, uncontrolled operation of Evaporator Fans
Measure Level Description	Evaporator Fan Controls installed in walk-in coolers or freezers save energy by turning off ('On/Off controls') or reducing the speed of ('two-speed controls') evaporator fans when the refrigeration compressor is not running, reducing the fan energy usage as well as the heat load on the refrigeration system from the fan motor.
Measure Efficiency Levels and Specifications	Based on applicable TRMs, runtime is typically reduced from 8,760 hours per year (continuous operation) to about 4,000 hours per year for both Freezers and Coolers.
Sizes	**Per fan controlled** (BGE, PEPCO, National Grid), **per controller** (Efficiency VT, Efficiency ME, DC SEU), or **per refrigeration unit** (PSEGLI) [Note: Controllers for 3-phase circuits, larger amperage and horsepower are not included in this analysis]
Distinguishing Features	**Two control types:** (1) On/off control turn off all but one or two fans when the compressor cycles off and are often used with refrigeration management systems that also control the compressor and defrost cycles. (2) Two-speed controls that run the evaporator fans at low speed when the compressor is off. This approach does not require a circulator fan.
Installation Scenarios	Typical Building Types: Grocery Store, Convenience Store, Restaurant Central control based on compressor run cycle or temperature differential across the evaporator coil.
Incentive Approaches and Qualifications	**VT (EVT):** - Minimum four fans or 250 watts per control. Controls must ensure fan energy is reduced by 70% when no refrigerant flows through the evaporator. **NH (PSNH, Unitil, Liberty):** No Prescriptive Incentive offered; Custom only. **ME (Efficiency Maine)**: No Control approach specified, incentive is per controller. **MA & RI (National Grid)**: available through National Grid Small Business Program - only for "ECM [fans] - Low and Medium Temperature" **CT (Groton Utilities)**: No Control Approach Specified, Custom incentive offered at $0.14 per kWh saved. **NY (ConEd):** Custom incentive offered at $0.16 per kWh saved. **NY (PSEGLI):** - Must control a minimum fan load of 1/20 horsepower - Must reduce fan motor power by at least 75 percent with the compressor(s) off **MD (BGE):** - Must control a minimum fan load of 1/20 horsepower - Must reduce fan motor power by at least 75% during the compressor off-cycle. **D.C. (D.C. SEU):** - Must turn off a minimum of four evaporator fans at least 70% of the time the compressor is not running, and must control a minimum fan load of 1/20 horsepower operating continuously at full speed. **MassSave:** Small Business D.I. Program

Table 16. Refrigeration Evaporator Fan Controls Base Cost Factor

Equipment Description	Base Cost Factor - BCF ($/control)
Evaporator Fan Control	**$562.69**

Note: This measure includes Full Equipment and Labor Costs

Table 17. Refrigeration Management Controls Cost Range

Equipment Description	Installed Cost Range ($/control)
Multifunctional Refrigeration Management Control	**Low $500 – High $1,700**

Findings Summary

As with the ASDHC measure, the market for Evaporator Fan controls is small in territories where there is no proactive DSM program, even in territories with generous utility incentives available. A trend in the market is toward multi-functional refrigeration management controls, including an Evaporator Fan Control. PAs should consider contracting an experienced implementer to stimulate the market and capture more savings from this proven technology through outreach and proactive marketing while being sensitive to the existing installers already in the marketplace. PAs should also consider incentivizing multi-functional refrigeration management controls.

Baseline Issues

- Because the baseline for Evaporator Fan Controls is no control (i.e. the evaporator fans run 24/7) this study reports the full installed cost of the EFC.

Applications

- There are two types of Evaporator Fan Controls, *On/Off* and *Two-speed* Controls. On/off control will turn all but one or two evaporator fans off when the compressor cycles off, while two-speed controls run the evaporator fans at low speed when the compressor is off.

- Our research revealed that the only controls using the On/Off control method were complex control modules - or more accurately, refrigeration energy management systems - that have numerous additional capabilities including control of the compressor cycle, the defrost cycle, the door heaters, the evaporator fans, outdoor air economizer and more. These controls use complex control algorithms using many more inputs than just a compressor cycle sensor (either delta-T or amp sensor), and they can control higher amperage than the stand alone EFCs. These controls can also log the various control parameters over time like an Energy Management System. Because of the impracticality of disaggregating the cost of the EFC function from these controls, these data points were removed from the analyzed data set and presented as a cost range in Table 16, above.

Information source(s)

- Cost data was gathered from the following sources:
  - Interviews with installation contractors and one manufacturer
  - Program tracking data
  - Internet search derived equipment costs
  - CPUC/Itron Measure Cost Study

Impacts on the ICS 4 Research

- For three of the PA territories where we were able to obtain data, the pricing of EFC installations was extremely regular, indicating a negotiated contract price for an approved installer. This finding was confirmed with the respective PAs. To reduce the undue influence of these negotiated prices, these data sets were distilled down to one data point for each contract territory using the average material and labor costs for that data set. The cost was also discounted by 20% as an estimate of the contract administration, marketing and outreach budget included in those contract prices.

Market Issues

- As discussed above, negotiated contract pricing dominates the market for at least three PA territories studied. In other NEEP territories, it appears that market penetration of this technology is minimal, based on the scarcity of program data collected.
- Presumably due in part to the falling cost of microprocessors and sensor technology, the trend in the refrigeration controls market seems to be toward microprocessor-based multifunctional control modules - or more accurately, refrigeration management systems - that have numerous additional capabilities beyond control of the evaporator fans, including control of the compressor cycle, the defrost cycle, the door heaters, outdoor air economizers and more. These multifunctional controls tend to use the On/Off control method for Evaporator Fans in order to optimize energy use particularly during defrost cycles.
- Since it is impractical to disaggregate the cost of the Evaporator Fan Control capabilities from the overall cost of these multifunctional units, the cost data for refrigeration management systems were not included in our overall analysis, but presented separately.(See Table 16, above)

Implications for Program Design

- Our data collection efforts suggested that the market penetration of Evaporator Fan Controls to date has been disappointing without proactive outreach efforts by individual installation contractors as noted in Massachusetts, Rhode Island, New York City and Maryland. This is understandable given the estimated $550 to $580 full installed cost of this technology. (Again, since the baseline for this measure is no control, the incremental cost equals the full cost.) This finding would seem to suggest that prescriptive financial incentives alone are not adequate to achieve the desired market penetration or potential energy savings yield of this technology.
- Because of the scarcity of data from regions without proactive outreach and marketing, we do not present these cost estimates as having captured the market with the same confidence as for other measures in this and prior phases.
- Our study also identified an emerging market trend toward microprocessor-based multifunctional control modules or refrigeration management systems that include Evaporator

Fan Controls among other capabilities. In the final analysis, we present a range of installed costs for these devices with the caveat that pricing can vary widely depending on the capabilities and capacities of each particular control. Although these devices are difficult to specify narrowly enough for a prescriptive incentive approach, Program Administrators should consider the results of this study as one input parameter for incentivizing refrigeration management systems as they gain wider acceptance.

- This appears to be an area in which further research to determine the most appropriate program designs could be useful. The market development in control modules may call for a separate approach from the relatively simpler fan controls initially characterized.

5.3.6 Commercial Infrared Heaters – Natural Gas

Table 18. Infrared Heaters Characterization

Baseline Description	Commercial Gas-fired Infrared Heater
Measure Scenario(s)	RET , ROB, NC
Baseline Efficiency Levels	Gas-fired Unit heater, standard thermal efficiency
Measure Level Description	Gas-fired high intensity or low intensity infrared heater. Infrared Heaters save energy compared to conventional forced hot air heating in that they mostly heat objects, people and surfaces achieving comfort for the occupants at a lower air temperature.
Measure Efficiency Levels	Efficiency levels not defined for this measure[9]
Sizes	Up to 50,000 BTUh > 50,000 BTUh up to 150,000 BTUh > 150,000 BTUh up to 175,000 BTUh Greater than 175,000 BTUh
Distinguishing Features of Efficient Measure	Low Intensity Infrared Heaters - usually forced draft or draft induced vented combustion, tube-style High Intensity Infrared Heaters – usually unvented with a compact rectangular shape
Installation Scenarios	Ceiling–mounted or hung overhead in large indoor spaces with low occupancy, like warehouses or aircraft hangars. High Intensity Infrared Heaters often installed in areas with good ventilation, like loading docks or the front end of large box stores
Incentive Approaches	CT: High or Low Intensity: $500 to $850 based on Btu/h output MA: Low Intensity only: $750 NYSERDA: Low Intensity only: $2.50/MBh ConEd: Low Intensity only, replacing existing gas heat: $500
Sources	MA TRM, NYSERDA, ConEdison, National Grid, Mass Save, Energize CT

Table 19. Infrared Heaters Base Cost Factor

Size Category	Base Cost Factor - BCF ($/unit)	
	High Intensity	Low Intensity

[9] There is no existing efficiency requirement for commercial low and high intensity infrared gas heaters .

Up to 50,000 BTUh	-$294.34	$469.97
> 50,000 BTUh up to 150,000 BTUh	-$277.94	$421.74
> 150,000 BTUh up to 175,000 BTUh	-$263.89	$380.40
Greater than 175,000 BTUh	-$254.52	$352.84

Findings Summary

Negative incremental costs were observed for high intensity infrared units across all size ranges. This means that on average this efficient alternative equipment costs *less* than the conventional or baseline equipment, suggesting that the Program Administrator need not provide cash incentives to promote adoption of this energy saving equipment. That finding, combined with the fact that high intensity infrared heaters are typically unvented, leads the study authors to recommend discontinuing any incentive programs for high intensity Infrared Heaters.

Since uptake of the low intensity infrared heaters measure is very low in all territories that offer prescriptive rebates, Navigant recommends that PAs consider launching a limited pilot program using proactive marketing and outreach to identify and overcome the barriers to adoption of this technology.

Baseline Issues

- The baseline for this measure was characterized as a commercial gas unit heater at 80% thermal efficiency across all size categories. For both low and high intensity measures, the baseline equipment was found to be about 10% higher capacity (Btu/h) due the infrared units being able to make occupants feel comfortable at a lower air temperature. This difference is due to the fact that Infrared Heaters transfer heat to objects and occupants directly via radiation rather than via forced hot air convection. For the conventional forced hot air heating system, the air in the space needs to be heated to a higher temperature to make the occupant feel warm.
- There was no efficiency requirement for commercial low and high intensity infrared gas heaters. This leads to a large disparity in cost for a particular size category. Manufacturers offer various models with differing features such as single stage, two stage, and modulating units. These features affect the energy usage of the units and also their cost. The lack of a standardized measure of efficiency makes comparisons between these units difficult.

Impact on the ICS Research

- Navigant made every effort to obtain program data, but was only able to obtain eleven program participant data points. These eleven data points were ultimately not used in the analysis due to uncertainties as to what equipment and installation costs were included. Only a total installed cost was provided, and without invoices, it was unclear what was included in that cost. As such, it was not possible to isolate material, labor, and other costs. Due to the lack of program data, it was necessary to obtain material cost through internet retailers. While this is not ideal, it provided a basis for which to compare our contractor provided data points.
- Manufacturer equipment costs were only available through their distributor networks and representatives. This information was not as readily available as internet reseller data due to the confidential and proprietary nature of that data. As such, it was more practical to obtain internet data to compare with our contractor interview data.

Market Issues

- Negative incremental costs were observed for high intensity infrared units across all size ranges. Negative incremental costs are due to the fact that high intensity units lack fans and other moving parts and do not need to be vented, both of which are characteristics of low intensity infrared heaters and baseline gas unit heaters. The data shows high intensity gas infrared heaters costing less to install than the baseline units.

Other Concerns, informative results not captured above

- Contractors we interviewed reiterated the importance of a well-designed infrared heating system; the effectiveness of the infrared heating system can vary drastically with design. As with other HVAC systems, a properly sized and designed system will offer better efficiency and comfort.

Implications for Program Design

- High intensity infrared units were only rebated through one program, while others required the commercial infrared be low intensity. Due to the negative incremental cost for high intensity units, it is recommended that only low intensity units be rebated.
- There was not enough data provided by program administrators to have a robust dataset based on rebated equipment. Additionally, the data that was provided was not usable due to the lack of detail. To improve the dataset for any future research on infrared heaters, it is recommended that detailed information be collected for any future units being rebated through program administrators.

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, 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 market share of appliances and equipment
- Changes in manufacturing that reduce costs (i.e., scaling up production due to 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 20. Measure Cost Shelf Life
shows expected shelf life for all ICS4 study measures.

Table 20. Measure Cost Shelf Life

Measure	Expected Cost Volatility	Comments
VFD and Load/No Load Air Compressors	Stable	Established technology in a mature market
Commercial Kitchen Fryers	Stable	Mature market.
Commercial Kitchen Convection Ovens	Stable	ENERGY STAR standards were recently enacted, but most manufacturers are able to meet the standards at little added cost. Many baseline models are being discontinued.
Refrigeration Anti-Sweat Door Heater Controls	Moderate	Trend is toward microprocessor-based refrigeration management systems, but sensors for simple controls are getting less expensive.
Refrigeration Evaporator Fan Controls	Moderate	Trend is toward microprocessor-based refrigeration management systems.
Commercial Infrared Heaters	Moderate	Small market. DSM programs have low uptake

KEY:
Stable - No expected Technology or Standards changes. Update for annual inflation only next 3-5 years.
Moderate - Codes/Standards or technology changes possible in 1-3 years.
High - Market/Technology changes will affect measure characterization and costs in 1-3 years.