Non-energy impacts of C&I energy efficiency measures provide substantial program benefits above carbon reduction

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ABSTRACT

Policy makers have long known, primarily on the basis of anecdotal evidence, that participants in energy efficiency programs experience many direct benefits beyond reductions in energy costs. For programs targeting commercial facility owners and occupants, these include increased life expectancy and improved performance of equipment, reduced maintenance of the retrofitted equipment, waste disposal, and product spoilage. These changes may lead to economic benefits such as increased sales, lower operations and maintenance costs, and worker productivity. Such benefits can greatly enhance the cost-benefit justification of energy efficiency programs. However, rigorous quantification of non-energy impacts of energy efficiency programs poses a number of methodological challenges – especially for commercial and industrial energy users, whose operations and business models are heterogeneous.

This paper presents the methods and results of a study that yielded statistically reliable estimates of the non-energy impacts (NEI) generated by an extensive set of commercial and industrial energy efficiency measures implemented with the support of utility programs in Massachusetts. The study used the results of in-depth interviews with 505 participants who had implemented 789 separate energy efficiency measures to identify and quantify their non-energy impacts. After interviewers identified categories of cost and revenues impacted and the general direction of those changes, deeper probes were used to determine the nature of those changes and specific metrics for quantifying the impact. This approach improved upon previous NEI survey efforts by having interviewers work with respondents to help them monetize the NEIs and ensure that the respondent thoughtfully considered the various sub-categories that could apply to an NEI.

Researchers used the results of the interviews to quantify non-energy benefits and costs associated with the measures. Researchers used a multi-step process to translate the qualitative interview responses into a quantitative NEI estimates. A set of standard formulas and metrics were identified for each cost and revenue center (i.e., the cost or revenue items) impacted under each NEI category. Standardizing the formulas across multiple measures allowed analysts to evaluate each in terms of the necessary metrics (i.e. salary, hours, price), and the range of responses to those metrics ($/hour).

These benefits and costs fell into the following categories: operations and maintenance cost, administrative cost, cost of supplies and materials, transport costs, product spoilage, waste disposal, fuel and water consumption, and sales and other revenue. Among the sample participants, researchers identified average NEIs for five prescriptive electric and six prescriptive[1] gas measure categories. The overall NEIs for prescriptive electric and gas were valued at $0.03 and $2.34 per kWh, respectively. Researchers also

[1] Prescriptive measures refer to frequently installed (common) energy efficiency measures that do not require a complex engineering analysis. These measures have pre-determined incentives.

identified average NEIs for three custom electric and four custom gas measure categories, with overall NEIs valued at $0.04 per kWh and $0.03 per therm, respectively.[2] Our research approach focused primarily on identifying annual NEIs for the life of the installed measure.

Introduction

This paper presents study results of the Massachusetts Cross-Cutting Evaluation Team's analysis of non-energy impacts (NEIs) attributable to 2010 commercial and industrial (C&I) retrofit programs. The study was administered by the Massachusetts Program Administrators (PAs). The goal of this study was to provide a comprehensive set of statistically reliable NEI estimates across the range of C&I retrofit programs offered by the Massachusetts electric and gas PAs. The study addressed the following objectives, separately for prescriptive and custom electric and gas measures:

1. Quantify participant gross and net NEIs per unit of energy savings; and
2. Determine the relationships between NEI / unit of energy savings and program attribution.

In the U.S., energy efficiency is considered the lowest-cost approach to reducing emissions and deferring the need for new capacity, thereby reducing costs to utilities and customers. State level utility commissions (e.g. Massachusetts, California) set annual energy reduction goals and require utilities to meet those goals. Energy efficiency programs are established to promote research and development to increase the efficiency of end-use technologies, accelerate the adoption of efficient end-use technologies, and accelerate the adoption of practices and behaviors that reduce energy use. Prescriptive incentive programs offer rebates per unit for efficient HVAC, lighting, motors, variable frequency drives, while custom incentive programs offer incentives per estimated kWh saved for a wide range of measures, based on detailed specifications & standard calculations. Cost benefit tests are performed to determine how programs should be designed, and which measures should be implemented. Once energy efficiency programs are implemented, they are also evaluated using a cost/benefit approach to assure recovery of 'lost revenues' to the utilities. Net energy and demand savings serve as the primary source of benefits, but firms may include other program induced impacts such as emissions reductions and non-energy impacts (NEIs).

NEIs include positive or negative effects resulting from energy efficiency measures, apart from energy savings. Non-energy benefits (NEB) is the term frequently used to refer to positive NEIs, while negative NEIs—non-energy costs— reflect ways that energy efficiency measures result in adverse effects. An example of a positive NEI is the reduction in labor costs associated with cleaning an oil fired furnace upon installation of a gas furnace. An example of a negative NEI is the increased maintenance costs incurred by added equipment from co-generation measures. NEIs (or NEBs) can be further distinguished as participant or societal. This paper focuses on participant NEIs, which are monetary and non-monetary benefits (positive or negative) that the program participant experiences.

DNV GL embarked on this study to fulfill the directive set forth by the Massachusetts State's Department of Public Utilities to update and improve NEI estimates for use in the PA's 2013 to 2015 energy efficiency three-year plan and future annual plans. The plans incorporate NEIs into cost/benefit ratios as an additional source of benefits (or costs) resulting from energy efficiency programs. The PAs also use study results to assist in program marketing.

[2] Custom measures are site-specific solutions that require complex engineering studies to determine the appropriate specifications. Savings and incentives are determined on an individual project basis.

Methodology

The NEI Study was based on survey data collected from a sample of 2010 C&I program participants for prescriptive and custom electric and gas programs. The sample was primarily drawn from the pool of respondents to the 2010 Massachusetts electric and gas free-ridership and spillover study[3, 4]. Using this pool allowed the evaluation team to examine the relationship between program attribution and NEIs. The research then used a large scale in-depth interview (IDI) effort to provide statistically significant NEI estimates across program type (prescriptive and custom),fuel types (electric and gas) and measure category. This is a substantial improvement over previous studies that resulted in statistically significant NEIs for only a limited set of measures.

While there is a wealth of literature surrounding NEIs, there is fairly limited current NEI research specific to C&I programs, and less specific to Massachusetts. Our approach built on the accomplishments of two previous studies that were the most current and directly applicable to the PAs' C&I energy efficiency programs.

- **TecMarket Works** (2007)[5] used an interview-based approach to obtain self-reported non-electric benefits for custom measure programs, separating NEIs into mutually exclusive business impacts that may result from the installation of energy efficiency measures.
- **Optimal Energy Inc.** (2008)[6] provided non-electric benefits associated with prescriptive C&I electric programs in Massachusetts using an engineering based approach. This study estimated facility operations cost changes resulting from newly installed lighting and energy management system (EMS) equipment, and clearly defined and documented the specific sources for cost savings resulting from the installed measures.

The present study incorporated elements from each of these studies. Our approach used self-reported responses to in-depth interviews to derive estimates of the same mutually exclusive NEI categories developed by Roth and Hall (2007).[7] We sampled 789 measures across prescriptive and custom energy efficiency programs, compared to 136 custom measures (99 respondents) used in the 2007 TecMarket Works study. Energy industry experts conducted the interviews and probed responses to identify the specific cost and revenue category impacted. Interviewers followed structured probes to extract information to estimate NEIs, similar to the engineering based approach used in the Optimal Energy study. These probes allowed respondents to express the NEIs in familiar terms (e.g., number of hours saved to change light bulbs and wages) rather than asking respondents to approximate values for abstract concepts such as the impact of energy efficiency lighting on operations and maintenance costs.

Interview guide and process

The research instrument provided interviewers with the needed flexibility while maintaining

[3]2010 Commercial and Industrial Electric Programs Free-ridership and Spillover Study: Final Report. Prepared for the Massachusetts PAs. Prepared by TETRA TECH. July 26, 2011.

[4] 2010 Commercial and Industrial Gas Programs Free-ridership and Spillover Study: Final Report. Prepared for the Massachusetts PAs. Prepared by TETRA TECH. September 20, 2011.

[5] TecMarket Works. "*Non-Electric Benefits from the Custom Projects Program: A look at the effects of custom projects in Massachusetts*" Prepared for: National Grid. Roth, Johna and Nick Hall. September 25, 2007.

[6] Optimal Energy, Inc. "*Non-Electric Benefits Analysis Update." D.P.U. 09-119.* Attachment AG-1-22 (j). Mosenthal, Phil and Matt Socks. November 7, 2008.

[7] For definitions of the NEI categories see: "Final Report – Commercial and Industrial Non-Energy Impacts Study." Prepared for the Massachusetts Program Administrators by DNV GL and TetraTech. June 29, 2012.

consistency in the data collected. The sequence of questions designed to elicit NEI information focused on thirteen NEI categories, as presented in Table 1 below. Questions were structured to prevent possible double counting across categories by presenting related categories sequentially for easier respondent recall. The interviewer protocols were designed to confirm that costs or savings included in one category were not included in any other categories. Once interviewers determined the NEI sources, they used additional closed ended questions to assess whether the respondent experienced an increase or decrease in each affected NEI (e.g., an increase or decrease in operations and maintenance costs as a result of the installed measure).

Table 1. Non-energy impact categories

NEI category	Probes						
	Labor[1]	Parts / materials	Training	Fuel[2]	Water	Fees / permits	Other
Operations & maintenance	✓	✓	✓	✓			✓
Administration	✓		✓				✓
Materials handling	✓						✓
Materials movement	✓	✓		✓			✓
Other labor	✓		✓				✓
Spoilage/defects	✓	✓					✓
Water usage					✓		
Waste disposal	✓	✓				✓	✓
Fees						✓	✓
Other costs							✓
Sales							✓
Rent revenues							✓
Other revenues							✓

1. Separate probes were added to distinguish between internal and external labor.
2. Fuel included: natural gas, no. 2 distillate, no. 4 fuel oil, propane, wood, and kerosene.

Respondents who were unable to provide overall NEI estimates outright were guided through a series of structured probes to determine whether respondents experienced any changes to various cost or revenue categories associated with each NEI category. For example, internal labor and external labor were identified as separate cost categories associated with Operation and Maintenance (O&M) costs. Once the interviewer identified the impacted cost and revenue categories, they used deeper probes to determine the nature of those changes and specific metrics for quantifying the impact. If a respondent indicated a measure affected their O&M costs, interviewers asked another series of questions to obtain the necessary information for imputing a value. If the respondent indicated that the installed measure decreased labor costs, interviewers asked them to estimate the number of hours that labor was reduced and the loaded (i.e. wages plus healthcare, vacation, and other benefits) or un-loaded cost (wages excluding healthcare, vacation and other benefits) of that labor.

Computing NEIs

DNV GL used a multi-step process to compute NEIs associated with each measure. This process began with the in-depth interview, and flowed into the data analysis process. During the interview, interviewers used their knowledge of the intersection of energy efficiency measures and business functions to identify an appropriate formula for estimating cost and benefit impacts resulting from the installed measures. This was the first step in estimating NEIs for each measure. In order to complete this step, the interviewer captured the following information during the interview:

- The relevant cost and revenue categories affected;
- The nature of those impacts; and
- Estimates for each parameter necessary to monetize NEIs.

Interviewers used the following basic formula to capture the necessary information for computing most NEIs:

Category NEI = (old category cost) – (new category cost)

Where

Category NEI = increase or decrease in cost for a particular NEI category
Old category cost = costs for that category prior to measure installation in 2010
New category cost = costs for that category after measure installation in 2010

A similar formula was used for changes to revenue associated with measures. Cost reductions and revenue increases were counted as positive NEIs, and the opposites as negative NEIs.

Interviewers probed to ensure that the pre and post measure installation time periods were typical, and adjusted if necessary. For example, if a respondent said they repaired a boiler four times per year, interviewers then asked questions to verify the frequency of the equipment maintenance. On occasion, the additional questions revealed that the repairs happened four times in 2009, but occurred only two times per year in previous years. Respondents were typically able to provide such information from memory, but occasionally referenced engineering records to confirm their responses. This information was used to revise the initial response. This formula compared the typical year prior to and after the measure installation, in most cases 2009 to 2011.

Data analysis and calculation of participant NEIs

Translating the qualitative interview into NEI estimates required the following multi-step process:

1. Identifying and coding cost and revenue categories affected for each NEI category – Responses to the detailed probes for each category were re-coded to delineate the specific cost and revenue changes resulting from the installed measures, as well as the specific metrics used to quantify those impacts. For example, the evaluation team first determined that internal or external O&M labor was impacted. Then they identified the direction of those impacts, as well as the hours impacted and the respondent's specific fully loaded wage associated with that change.

2. Ensuring consistency across interviewers and data analysts – Responses to open ended questions often varied across respondents. The evaluation team ensured consistency by having a second analyst responsible for reviewing all data entered, as well as verifying and standardizing data coding.

3. Constructing a standard set of formulas for computing NEIs –The evaluation team identified a set of standard formulas and metrics for each cost and revenue category (i.e., the cost or revenue items) impacted under each NEI category. Standardizing the formulas across multiple measures

allowed analysts to evaluate each in terms of the necessary metrics (e.g., salary, hours, price), and the range of responses to those metrics ($/hour).

Table 2 presents the formulas used to calculate overall NEIs for operations and maintenance. As seen in the table 38 out of 290 respondents provided operations and maintenance internal labor NEIs outright. While not shown in the table, we found that roughly half of respondents also were able to provide values outright across most NEI categories. The cost/revenue category level expressed NEI questions in terms that respondents were more familiar with than asking them to monetize overall NEIs or the NEI category level.

Table 2. Formulas used to calculate overall NEIs for operations and maintenance NEIs

NEI Category	Cost/Revenue Category	Formula	Measures using formula n=x
Operation and Maintenance	Internal Labor	(Hours per year due to Old Equipment * Hours per year due to New Equipment)*Loaded wage per hour	145
		(Hours per year due to Old Equipment * Hours per year due to New Equipment)*Unloaded wage per hour	20
		(Hours per year due to Old Equipment * Hours per year due to New Equipment)* Times per year*Loaded wage per hour	10
		(Hours per year due to Old Equipment * Hours per year due to New Equipment)* Times per year*Unloaded wage per hour	1
		Hours per year due to New Equipment*Loaded wage per hour	9
		Hours per year due to New Equipment* Unloaded wage per hour	2
		Hours per year due to Old Equipment*Loaded wage per hour	49
		Hous per year due to Old Equipment * Times per year * Loaded wage per hour	7
		Hous per year due to Old Equipment * Times per year *Unloaded wage per hour	6
		Hours per year due to Old Equipment* Unloaded wage per hour	3
		No Calculation Required- Value stated upfront	38
		Operation and Maintenance Internal Labor Total	**290**

4. Identifying incomplete and incorrectly calculated NEIs – Assigning interview responses to the standard formulas enabled data analysts to identify incomplete, incorrect, and illogical responses.

5. Adjusting NEI estimates for replace-on-failure measures – The purpose of this study was to only determine NEIs that can be attributed to the programs. During the quality control process, the evaluation team realized that a number of NEIs resulted from measures that were either replaced on failure of the existing measure or replaced a functioning measure that was scheduled to be replaced immediately. Because these measures would have been replaced regardless of program

incentives, any NEIs attributable to the measure being new as opposed to being energy efficient cannot be attributed to the program. The evaluation team determined that the portion of the NEI associated with these measures' "newness" was not applicable to the program because the participant would have incurred that benefit or cost without the program. To identify replacement on failure measures, we reviewed the response categories for the timing-related attribution questions provided from the 2010 Massachusetts electric and gas free-ridership and spillover study, or that had been asked of the NEI study participants. Measures for which the program had not affected the timing of installation were considered replacements on failure. For these measures, we multiplied the estimated NEI by the percent of the reported change that NEI interview respondents indicated was due to the measure being new verses energy efficient

6. Identifying double counting of NEIs – By reviewing the sources of each reported NEI, their descriptions, and metrics, the evaluation team ensured that a single effect was not counted for multiple NEI categories, such as internal O&M labor and administrative costs.
7. Eliminating invalid NEIs - Occasionally, respondents reported NEIs that should not be included in the analysis. For example, one respondent reported high "other revenue" resulting from clean energy credits revenues earned from emissions trading).The PAs' already adjust for clean energy benefits in their benefit-cost models. Rather than risk double counting, this benefit was excluded.
8. Imputing missing values – Approximately 40 respondents provided incomplete information for computing one or more of the NEIs for a measure. We used the mean value of the missing cost or revenue metric per NEI category to impute values for partial responses. This reduced standard errors without biasing the results.
9. Computing total NEIs - The last step in the data coding and quality control phase was to calculate total NEIs for the measure. We used the statistical procedure of ratio estimation to develop estimates of NEI per unit of energy savings. Ratio estimation extrapolates measure level NEIs to the population of measures, allowing for direct computation of the ratio of NEI (in dollars) to reported savings for the sample.[8] Our research approach focused primarily on identifying annual NEIs for the life of the installed measure. We used the average NEI values and average cost and revenue changes as a means for detecting extreme values. Where necessary, we replaced extreme values with imputed values according to the procedure outlined instep 8, or coded them as missing.

Analysis of attribution

A second objective of the study was to examine the relationship between NEIs and program attribution. This objective sought, in part, to determine whether NEIs can contribute positively to program effectiveness when programs successfully use NEIs to help promote energy efficiency decisions, but can contribute to free ridership if the NEIs are well known to customers without program assistance, prior to their purchase decisions.

If customers tend to learn about positive NEIs from the program and those NEIs contribute to the

[8] The ratio is a combined ratio estimator, calculated as the weighted sum of NEI to the weighted sum of savings, using the same sample points and weights for numerator and denominator.

purchase decisions, the NEIs contribute to lower free ridership and higher program attribution. Consequently, this objective also sought, in part, to determine whether higher NEIs will be associated with higher attribution. If so,, multiplying average attribution by average NEIs will understate the attributable NEIs.

On the other hand, if customers tend to know about NEIs without help from the program and the NEIs contribute to the purchase decisions, the opposite is true: NEIs contributes to higher free ridership and lower attribution. Moreover, higher NEIs will tend to be associated with lower attribution. As a result, in this scenario, multiplying average attribution by average NEIs will overstate the attributable NEIs.

Finally, multiplying average attribution by average NEIs will provide a good estimate of the attributable NEIs if there is no particular association between NEIs and attribution, which will be true if one of the following conditions holds:

- If these two tendencies are equally prevalent; or
- If there tend to be no NEIs anticipated before the purchase; or
- If the potential for NEIs doesn't contribute to purchase decisions, .

Our study was designed to explore the relationship between NEIs and attribution by collecting NEI data from customers for whom we also had an understanding of their level of program attribution, as identified by a score indicating the percent of savings that can be attributed to the programs, removing free ridership (savings from participants who would have installed measures absent the program incentives) and adding in spillover (savings resulting from measures installed without program incentives but influenced by program support of separate measures or locations). We used four separate methods to explore the relationship between program NEIs and program attribution:

- A high level comparison of overall NEI values by attribution scores;
- A visual inspection of plots of NEI to energy savings ratios and attribution scores;
- An examination of the correlation statistics for NEI to energy savings ratios and attribution scores;
- A comparison of 2 methods to estimate net NEIs.

The first method of calculating net NEIs is correct if there is no overall correlation between NEIs and attribution. This is a simpler method and has been used by the PAs in the past. The second method is appropriate whether or not there is a correlation, positive or negative, between NEIs and attribution. This method is more complete, but also more complicated to apply.

Our analysis applied the attribution rate from the 2010 participant free ridership and spillover study for each respondent to the gross NEIs estimated in the present study. This provided a revised estimate of net NEIs specific to each respondent. We then calculated the average net NEI by reporting category, and compared it to the net NEIs using the traditional approach, and compared the two approaches.

Results

Analysis of NEIs

Our analysis identified the presence of statistically significant NEIs resulting from energy efficiency programs. These results are summarized in Table 3 below.

Prescriptive electric. HVAC measures, which included air conditioning, air handling units, and chillers, showed the highest estimated NEI ($0.097/kWh), as well as the largest average NEI ($7,687 per measure). Lighting showed the second highest NEI, both in terms of NEI / kWh ($0.027/kWh) and average NEI ($1,636 per measure). Estimating NEIs associated with lighting measures is simpler than for other types of measures, because NEIs largely consisted of reduced time replacing bulbs and decreased disposal costs.

Prescriptive gas. Building envelope measures resulted in the highest NEI both in terms of NEI/kWh ($105/kWh) and average NEI ($1,551 per measure). This category included measures such as insulation and energy efficient windows and doors. Many of the NEIs for building envelope measures resulted from savings in operations and maintenance due to reduced labor in repairs and equipment replacement. HVAC measures, which included gas boilers, furnaces, and chillers, resulted in the second largest average NEI ($755 per measure) and second highest estimated NEI per kWh ($39.48/kWh). Most HVAC NEIs were reported as operation and maintenance savings. Through the use of energy efficient HVAC equipment, respondents stated that there was a decrease in time spent on labor and cost incurred for parts and supplies. There were fewer NEIs reported for water heater savings. However, respondents did note that after the water heater was installed, there was virtually no maintenance required. Consequently, while no statistically significant NEI was detected, savings on maintenance costs is likely to result from these measures.

Custom electric. CHP/Cogeneration measures showed the highest negative estimated NEIs (-$12,949 per measure). This is due to the additional energy efficient equipment required increasing preventative maintenance and increased administrative costs. The Other category showed the highest average NEI ($15,937 per measure). This category contained a variety of measures including building envelope, compressed air, process and other end uses. Custom lighting showed the highest NEI in term of NEI/kWh ($0.059/kWh) and the second highest in average NEI ($5,686 per measure).

Custom gas. HVAC, which included measures such as boilers, furnaces, and gas chillers, showed the highest estimated average annual NEI ($2,798 per measure). Building Envelope, which included measures such as insulation, windows, and doors, had the second highest estimated average NEI ($922 per measure) and the second highest NEI/Therm ($13.99/kWh).

We also identified that there was a significant correlation between program energy savings and the level of NEIs reported. The evaluation team found a strong and statistically significant correlation between NEIs and energy savings for the following measures: prescriptive electric, custom electric and custom gas. We also found a statistically significant correlation between NEIs and savings for prescriptive gas, but this result was not as strong, largely resulting from the low sample size. While we did expect to see a significant correlation between the level of savings and NEI values since larger measures are likely to result in greater cost or revenue changes, previous studies (Hall 2007) were unable to detect significant correlation, most likely due to a small sample size.

Table 3. Summary of average annual NEI estimates

Electric measures	n	Average Annual NEI per Measure*	NEI/kWh	90% CI Low	90% CI High	Stat Sig
Precriptive						
HVAC	27	$ 7,687	$ 0.0966	$ 0.0544	$ 0.1389	Yes
Lighting	163	$ 1,636	$ 0.0274	$ 0.0176	$ 0.0372	Yes
Motors and Drives	50	$ 541	$ 0.0043	$ (0.0005)	$ 0.0091	No
Refrigeration	30	$ 5	$ 0.0013	$ (0.0002)	$ 0.0028	No
Other	32	$ 28	$ 0.0039	$ (0.0002)	$ 0.0079	No
Total	*302*	*$ 1,439*	*$ 0.0274*	*$ 0.0188*	*$ 0.0360*	*Yes*
Custom						
CHP/Cogen	6	$ (12,949)	$ (0.0147)	$ (0.0247)	$ (0.0047)	Yes
HVAC	20	$ 5,584	$ 0.0240	$ 0.0003	$ 0.0477	Yes
Lighting	89	$ 5,686	$ 0.0594	$ 0.0318	$ 0.0871	Yes
Motors and Drives	42	$ 1,433	$ 0.0152	$ (0.0005)	$ 0.0309	No
Refrigeration	90	$ 1,611	$ 0.0474	$ 0.0244	$ 0.0705	Yes
Other	29	$ 15,937	$ 0.0562	$ 0.0038	$ 0.1087	Yes
Total	*276*	*$ 4,454*	*$ 0.0368*	*$ 0.0231*	*$ 0.0506*	*Yes*
Gas measures	**n**	**Average Annual NEI per Measure***	**NEI/kWh**	**90% CI Low**	**90% CI High**	**Stat Sig**
Prescriptive						
Building Envelope	2	$ 1,551	$ 106.0306	$ 77.4829	$ 134.5783	Yes
HVAC	50	$ 755	$ 39.4909	$ 15.9353	$ 63.0466	Yes
Water Heater	47	$ 129	$ 7.6386	$ (0.0348)	$ 15.3120	No
Total	*99*	*$ 439*	$ 24.4714	$ 10.6578	$ 38.2850	*Yes*
Custom						
Building Envelope	46	$ 922	$ 14.0013	$ 3.6883	$ 24.3144	Yes
HVAC	41	$ 2,798	$ 6.7199	$ 4.4639	$ 8.9759	Yes
Water Heater	23	$ 803	$ 5.3508	$ (14.5258)	$ 25.2274	No
Other	2	$ 1,905	$ 15.4066	$ (165.9399)	$ 196.7532	No
Total	*112*	*$ 1,940*	$ 7.2522	$ 4.3705	$ 10.1339	*Yes*

*Equals (NEI/kWh) x (Average annual kWh); **Equals (NEI/therm) x (Average annual therms)

Analysis of attribution

Of the four analysis methods used to examine attribution, two showed some evidence of a relationship between NEIs and attribution: the correlation analysis and the comparison of net NEI estimation methods. In both cases the strongest evidence came for the motors and drives reporting category, which played a small role in the program's overall NEI estimates. The high attribution findings from the free ridership and spillover study may have prevented us from seeing more evidence. Eighty-five percent of the sample for electric and 61 percent of the sample for gas had attributions above 75 percent.

- *High level comparison of NEI values and attribution scores* – We compared the average NEI and attribution values to determine if a relationship existed between the two metrics. Our ability to identify trends was limited by the low number of cases with zero or low attribution, and high number of cases with 100 percent attribution. However, the data did indicate that higher NEI to savings ratios for both electric and gas measures tend to correspond with low to zero attribution.

- *Visual inspection of NEI values and attribution score* - The next analysis examined the relationship between attribution and the ratio of NEIs to savings by reporting category graphically. Measures with the highest NEI to savings ratios frequently also had high attribution. However, the majority of the measures with low NEI to savings ratios also had high attribution. The lack of diversity in attribution obscured our ability to discern relationships through visual inspection.
- *Correlation of NEI to energy savings ratios and attribution* - We examined the Pearson correlation between the "NEI to savings ratio" and attribution. The correlation results provided some evidence of a relationship between NEIs and attribution. Four out of five statistically significant correlations were negative, meaning as NEIs increase, program attribution decreases.[9]
- *Comparison of approaches to estimating net NEIs* – Finally, we compared the ratio of net NEIs to gross savings using the current calculation method used by the PAs and two alternative calculation methods. Different methods of calculating net NEIs were used in an effort to determine whether the current method of calculation is systemically under- or over- estimating net NEIs. For electric measures, the overall value of the NEI to savings ratio was consistent in each approach.

Conclusions

This is one of the largest and most comprehensive and systematic studies of nonresidential NEI conducted to date. In addition to developing quantitative NEI factors for future program planning and valuation, the study explored the relationship between NEIs and program influence on participant decisions. We used energy experts to conduct in-depth interviews, rather than using a survey house to administer a standardized survey with close-ended questions. This enabled interviewers to probe deeply into potential sources of NEIs and extract information regarding specific cost and revenue changes resulting from the installation of energy efficiency measures. These probes allowed respondents to express the NEIs in terms with which they were familiar. This resulted in a relatively high proportion of respondents that were able to quantify NEIs, and reduced the number and magnitude of extreme values. Further, our approach enabled us to examine the specific cost and revenue assumptions used to estimate NEIs, and determine whether the respondent's internal calculations included the necessary parameters for computing cost or revenue impacts. Finally, because NEI estimates were computed from standard sets of formulas, we were able to extend NEI estimates into future time periods by simply revising the individual cost and revenue parameters based on publically available data or smaller scale survey research without repeating the interview process.

Our analysis clearly identified the presence of NEIs resulting from energy efficiency programs, and significant correlations between the program savings and the level of NEIs reported. We found statistically significant NEI per gross kWh and NEI per gross therm savings for three out of six prescriptive electric end uses and three out of four prescriptive gas measure categories. We found statistically significant NEI per gross kWh and NEI per gross therm savings for six out of seven custom electric end uses and three out of five custom gas measure categories. We also found statistically significant correlations between NEI values and gross energy savings for prescriptive and custom electric, as well as custom gas measures. Only prescriptive gas measures did not show a statistically significant correlation due to the relatively low sample size. Further, our analysis showed some indication of negative correlation between the NEIs and attribution levels, but mostly for measures that are small parts of the program. This finding does suggest that further investigation of the relationship between attribution rates and the level of NEIs is warranted, but overall, the

[9] Pearson correlation coefficient is a measure of the linear relation between two sets of data, i.e. how they move together..

simple method of applying the attribution rate on savings to NEI is sufficient for estimating net NEIs. However, it is important to note the following study limitations:

- Our research approach focused primarily on identifying annual NEIs. Consequently, the results may under estimate NEIs associated with one-time costs or benefits.
- The NEI estimates provided by this study were largely influenced by O&M cost reductions. In a number of instances this change in O&M costs resulted from decreased repair costs associated with the new, high efficiency (high quality) equipment. Due to the number of assumptions required to depreciate the installed equipment and amortize the cost differential, our estimates assumed that this cost differential occurs annually, over the life of the equipment. This may over estimate NEIs associated with older measures. Further research is required to examine the appropriate treatment of NEIs associated with maintenance over time.
- NEIs may be under or overestimated simply due to the nature of self-report surveys. Survey respondents were frequently able to identify NEIs, but we found that, for the same measure type, there was variance with respect to whether respondents were aware of particular cost and revenue changes that may occur.
- There was an increased chance of self-selection bias because much of the sample consisted of people who agreed to be interviewed twice. This was true for all of the prescriptive measures and many of the custom measures.
- The following factors may limit the applicability of NEI estimates in other jurisdictions:
  - ✓ Values were specific to Massachusetts customers. For example, the general cost of labor in MA may be higher than that in a Midwestern state. In order to apply these values to other jurisdictions, researchers should take care to make adjustments for differences in cost parameters (wages, benefits, prices of parts and supplies, hours worked), as well as differenced in the mix of measures installed in the respective jurisdiction for a particular measure category.
  - ✓ The mix of measures assumes C&I programs that are retrofits, which consisted of a mix of early replacement and replace-on-failure measures. Additional steps should be taken to address new construction.
- The following limitations may apply to the applicability of this research to future years:
  - ✓ The confidence intervals reported do not correct for the 2010 population size.
  - ✓ Significant program changes in terms of mix of measures, or favoring early replacement over replace on failure could make the NEI values from this study less applicable.

Non-energy impacts represent important factors in determining the true value of installing energy efficiency measures to participants, utilities, and policy makers. This study showed that C&I program participants realize substantial cost savings and revenue increases resulting from the installed measures. By asking participants to express those cost and revenue changed in familiar terms, they are able to conceptualize and quantify the changes that result from the installed measures. Policy makers, energy providers, and program implementers can use these quantified values to support regulatory support for energy efficiency programs as a means of reducing emission, the value of evaluating alternative program designs, or providing customers with a sense of the value proposition of installing energy efficient solutions.