Life-Cycle Cost Analysis Provides Powerful Tool for Estimating Non-Energy Impacts of Energy Efficiency Measures in New Construction Programmes

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Abstract

While policy makers in the EU focus on a multiple-benefits approach when assessing the overall impacts of Energy Efficiency, for commercial and industrial measures, US-based firms have worked to improve tools used to measure operational cost and revenue changes resulting from energy efficient measures in the commercial and industrial sector. These participant non-energy benefits (NEBs) provide policy makers, program administrators, and customers with substantial near-term benefits that can greatly enhance the cost-benefit justification of energy efficiency programs. [i, ii] Within the commercial and industrial sector, quantification of participant benefits has largely relied on self-reported responses to surveys. Until recently, engineering-based NEB estimation techniques have been largely limited to benefits associated with lighting measures.[iii] However, for new construction projects, the survey-based approach was limited due to respondents' inability to conceptualize baseline conditions for new facilities. Therefore, the present study turned to an engineering-based approach to estimate NEBs resulting from measures installed on new construction projects. Our research used this approach to document the facility cost outlays for energy efficient and baseline technologies. We determined the net present value of the life-cycle cost difference as a measure of participant NEBs. Our analysis resulted in engineering-based life-cycle cost differences for 33 prescriptive and custom electric and gas new construction measures providing roughly $488,000 in savings per year, across 956 measures identified in 2013.

Introduction

Energy efficiency (EE) programs are typically designed to improve the cost effectiveness of and stimulate investment in energy efficient technologies through offering incentives that decrease the capital cost of these investments. Energy-efficient technologies often consist of high-end alternatives to standard or baseline-efficiency equipment, they often result in changes to the costs and/or production capability of facilities. These changes to economic efficiency constitute participant program-attributable non-energy benefits (NEBs) that should factor into the participant's, utility, and policy-maker's overall benefit cost assessment individual measures as well as the portfolio of energy-efficiency programs. NEBs include positive benefits or negative benefits (non-energy costs[iv]) attributable to energy efficiency programs apart from energy savings. *"Participant benefits (or NEBs)* are monetary and non-monetary benefits (positive or negative[v]) that directly benefit a program partner, stakeholder, trade ally, participant, or the participant's household."

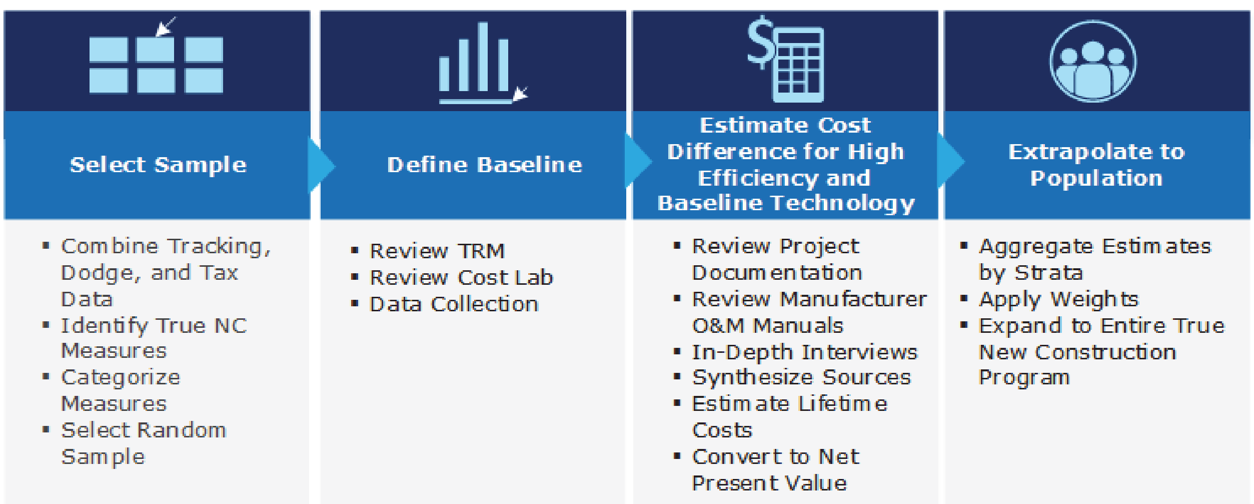
This paper presents study results of the Massachusetts Cross-Cutting Evaluation Team's analysis of Non-Energy Impacts (NEB) attributable to 2013 new construction programs administered by the Massachusetts Program Administrators (PAs). The study focuses on participant NEBs that are identifiable, measurable, and quantifiable by program participants as changes to their economic efficiency through impacting costs or revenues of participating organizations. The purpose of this study was to quantify the dollar value of participant NEBs for C&I NC projects completed in 2013, and to estimate gross NEBs per unit of energy savings resulting from NC electric and gas measures separately.

Methodology

For this evaluation, we used an engineering cost-estimating approach to determine NEBs for true NC projects.[vi] [vii]We limited the analysis to impacts on operations and maintenance costs. Previous research shows that other sources of NEBs may also result from energy efficiency measures; however, this study was limited to NEBs resulting from life-cycle cost differences due to the use of an engineering based approach. While in-depth interviews were not used to obtain NEB estimates, we did conduct a limited number of interviews with building owners, engineering firms, and public officials to inform the analysis and provide specific values of parameters needed in the engineering analysis.

Error! Reference source not found. provides a high-level overview of our approach, which consisted of four general steps.

Figure 1. Overview of NEB Estimation Process



1. First, we combined the PAs' tracking data with the Dodge Players database[viii] and tax assessors' data to isolate true NC projects, and then selected a sample of measures by measure category categories (i.e. categories PAs use in their benefit-cost (BC) analysis).

2. Next, we reviewed the Massachusetts Technical Reference Manual (TRM)[ix], data contained in and required by Cost Lab, and other sources to construct data collection instruments and define the appropriate baseline for each sampled measure.

3. In the third step, we estimated the difference in the net-present value of the average annual life-cycle cost between the baseline and energy-efficient technologies to reflect the NEB for

each sampled measure. Primary sources for this step were manuals produced by equipment manufacturers detailing operations and maintenance costs and in-depth interviews.

4. Finally, we computed the average NEB per unit of energy savings to identify statistically significant NEBs for each of the measure categories used in the PAs' BC analysis.

Sample design

We selected the sample in a way that produces an optimally allocated sample for NEB ratio or factor estimation—in this case, NEB$/unit of energy saved. Our sample consisted of 50 custom electric measures drawn from 9 measure types, 114 prescriptive electric measures drawn from 6 measure types, 30 custom gas measures drawn from 7 measure types, and 60 prescriptive gas projects drawn from 4 measure types. This resulted in an overall sample of 254 true NC measures out of a population of 956 measures in the 2013 program tracking data.

Selecting baselines

After stratifying and selecting the sample of measures, the first step in estimating NEBs for each measure was to define the baseline technology from which we could measure facility cost changes relative to the installed technology. When estimating NEBs for specific measures, the choice of baseline is crucial. Specific features of the equipment will dictate the maintenance and repair schedules. For prescriptive measures with baselines defined in the TRM, we used those TRM baselines. The TRM is typically based upon the International Energy Conservation Code (IECC) prescriptive code-compliance path. For example, an efficient centrifugal chiller is compared to a less efficient centrifugal chiller.

However, we could utilize TRM baselines only to the extent that they gave us the information we needed. This was limited, because the TRM does not always identify the baseline and efficient equipment features that correlate most strongly with NEBs. As an example, the TRM does not specify a baseline compressor type for the High-Efficiency Air Compressor measure. In cases where the TRM did not specify the applicable equipment characteristics, or where the TRM did not speak to the choice of baseline at all (such as for custom measures), we aimed to select the most commonly installed code-compliant equipment type using our own expertise and experience, as well as the results of our in-depth interviews, to inform the choice of baseline.

Performance path-based projects, classified as a single BC measure category "Custom – Comprehensive Design Analysis (CDA)," posed a particular challenge for identifying baseline technologies. These performance path-based projects involve the installation of multiple measures across multiple measure categories (e.g., lighting and HVAC) but receive incentives based on the extent to which the new or renovated building or building system as a whole exceeds the efficiency required by code. As noted, for prescriptive and custom measures that are not performance path-based, the baseline is defined in comparison to a specific piece of equipment, using the TRM as a guide where applicable. For performance path-based projects, however, the baseline is not defined based on the equipment but for the building or building system as a whole. The baseline is typically defined by the building simulation modeling assumptions identified in ASHRAE Appendix G[x]. In this situation, the baseline for a centrifugal chiller installed in a CDA project could be a screw chiller or even several unitary rooftop units.

To assist in the development of baseline conditions for the performance path-based measure, DNV GL requested that the PAs provide full documentation of the projects. In some cases, the program documentation clearly communicated how the baseline was defined. Where this was missing, the Evaluation Team members used their industry experience and, where appropriate, customer interviews, to determine which baseline code-compliant building system would mostly likely have been installed in the absence of program support for the energy-efficient system actually installed.

Estimating the cost differences between baseline and energy efficient technologies

To estimate the cost differential between the baseline and energy efficient technologies, we constructed detailed cost schedules for the baseline and energy-efficient technologies, which formed the basis for the NEB estimates. We used published data, our technical knowledge, and reported maintenance and replacement schedules outlined in the manufacturer O&M manuals, supplemented with information obtained from the in-depth interviews to develop or corroborate these costs. We classified costs into the following three types for further analysis:

- *Annual maintenance* – Routine maintenance recommended by manufacturers, such as annual oil changes for reciprocating air compressors.

- *Periodic repair* – Many types of equipment require repairs during their lifetimes, such while other types are not repaired but simply replaced. For example a reciprocating air compressor will require a rebuild every three years, while a screw compressor does not.

- *Replacement* – For equipment for which the baseline option is likely to fail before the end of the useful life of the energy-efficient equipment, we included and amortized the cost of replacement of the option with a shorter lifetime. We considered the type of equipment that would be installed as a replacement to represent the baseline condition. Through the in-depth interviews we found that owners replace equipment in-kind with similar equipment in most cases, except for lighting. Given the rapid adoption of more energy efficient LED lighting, we assumed that baseline lighting equipment would be replaced in-kind with a similar type of lighting for the first replacement cycle, but with LED lighting for subsequent replacement cycles.

Once we developed the NEB cost schedules and cost breakdowns, we computed the net-present value (NPV) of the average annual life-cycle cost difference between the baseline and energy-efficient equipment. We assumed the following in computing the NPV of life-cycle costs:

- *Planning horizon* – For each line item, we defined the measure life of the longer-lasting piece of equipment (installed or baseline) to contrast the life-cycle costs.

- *Discount rate* – We applied a real discount rate of 0.44%. While the PAs report a nominal rate of 2.54% in their 2016–2018 Three-Year Plan, however, the PAs indicated that their benefit cost models are actually based on a real rate of 0.44%.[xi]

- *Capital replacement* – Equipment replaced prior to the end of the planning horizon was assumed to be replaced in-kind and amortized over its useful life. The annual payment of that equipment appeared as a liability starting in the year the equipment was replaced until the end of the planning horizon.

Example of cost differences – lighting measures

Table 1 provides an example of this process for lighting measures. The table includes all of the costs associated with the maintenance and repair of the fixtures over the 15-year lifetime defined in the TRM. For presentation purposes, these costs are aggregated to reflect the cost per fixture, assuming three lamps per fixture.

The table shows that both T8 and T5 fixtures require lamp changes approximately every three years, and replacement fixtures every five years. However, LED fixtures require replacement every ten years. Further, because T5s and LEDs are brighter than T8s (baseline), they require fewer fixtures to light a given area, reducing the labor and equipment costs associated with the lamp replacements. We used differences such as these to calculate the NPV of the average annual life-cycle cost difference in owning each technology. The difference between the average annual cost difference between the baseline and energy-efficient technologies reflects the NEB associated with that measure.

The Evaluation Team decided that we would assume that a fixture is replaced with the same kind of fixture during its first replacement in the analysis period. The second time it is replaced, it is replaced with an LED fixture. The grey areas in **Error! Reference source not found.**Table 1 represent this time period during which bulb changes are no longer necessary due to the LED being installed.

The values in red represent costs that occur during the analysis period but for which the entire value is not captured during the analysis period. For these items, we amortize the value of that cost over the lifetime of its utility, take a single year's worth of that amortized cost, and apply it to each year of the analysis period after its occurrence.

For example, in the table below a T8 fixture is presumed to be replaced with an LED fixture in year 10. LED fixtures last ten years, but there are only five years remaining in the analysis period. Therefore, we amortized the cost of the LED fixture over ten years to get $14 per year. Applying this $14 for each of the remaining five years accounts for the fact that the LED fixture will continue to be installed after our analysis period (for five more years), and so much of its value remains.

Table 1 Example of NPV of Cost Differences for a Sampled Lighting Fixture Measure (Assuming 3 Lamps per Fixture) *

Type	Cost Category	Costs by Year (values measured in dollars)															Net Present Value		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Measure Totals		NEI
Baseline T8	Bulb Change	0	0	9.9	0	9.9	0	0	9.9	0	0	0	0	0	0	0	29	209	129
	Recycle	0	0	3.2	0	3.2	0	0	3.2	0	3.2	0	0	0	0	0	12		
	Fixture Replacement	0	0	0	0	89	0	0	0	0	14	14	14	14	14	14	168		
Efficient LED	Bulb Change	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81	
	Recycle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Fixture Replacement	0	0	0	0	0	0	0	0	0	14	14	14	14	14	14	81		

*Items shown in bold/red indicate capital costs incurred at some future year. Since the expected life for those costs extends beyond the analysis period, we limited the portion of costs used in the NEB computation to the annual costs incurred during the analysis period.

Example of cost differences – (Special Case) performance path-based measure category

This section describes our approach for estimating NEBs associated with the performance path-based (CDA project) measure. Estimating NEBs for the performance path-based measure category requires a different approach than that used for prescriptive or traditional custom measures. Custom-comprehensive projects are incentivized based on the extent to which the savings from the overall project (or collection of individual measures installed) performs relative to the applicable baseline or code (as modeled). Our approach to estimating the NEBs for the performance path-based measure includes seven general steps:

1. *Select a sample of CDA projects – We selected a sample of* CDA projects (both electric and gas) from the 2013 program tracking data. This step is similar to the first step in estimating NEBs in other measure categories. However, it is important to note that these projects were listed in the tracking data under a single measure category (i.e., CDA – Electric or CDA – Gas) and did not indicate which individual measures or technical equipment were actually installed. The sample of projects drawn included 8 custom-comprehensive electric projects and 8 custom-comprehensive gas projects.

2. *Identify line items (the specific equipment) installed from paper documentation* – Because many of the records in the program tracking data did not provide detailed descriptions of the actual measures/technologies installed, we requested that the PAs provide the paper project documentation detailing the measures installed on each sampled project. The paper documentation contained the necessary information for identifying the measures/technologies installed, identifying the baseline, and estimating life-cycle costs. We used this information to estimate NEBs associated with each line item installed using the subsequent steps.

3. *Identify the baseline technologies* – Incentives for the performance path-based measure are based on the extent to which the new or renovated building or building system (as a whole) exceeds the efficiency required by code. Selecting the baseline was particularly challenging because the baseline is not defined based on the equipment, but for the building or building system as a whole. For example, the baseline is typically defined by the building simulation modeling assumptions as defined in ASHRAE Appendix G. In this situation, the baseline for a centrifugal chiller installed in a CDA project could be a screw chiller or even several unitary rooftop units. We relied on the paper documentation to assist in defining the baseline for each installed measure or technology. In some cases, the program documentation clearly

communicated how the baseline was defined. In cases where the baseline was different than that assumed for prescriptive measures, we used the alternate baseline provided in the project paperwork. The chiller portion of the example below Figure 2 provides one example of this. Where the PAs were not able to provide paper documentation, the Evaluation Team used its industry experience and, where appropriate, customer interviews, to determine which baseline code-compliant building system would mostly likely have been installed in the absence of the program.

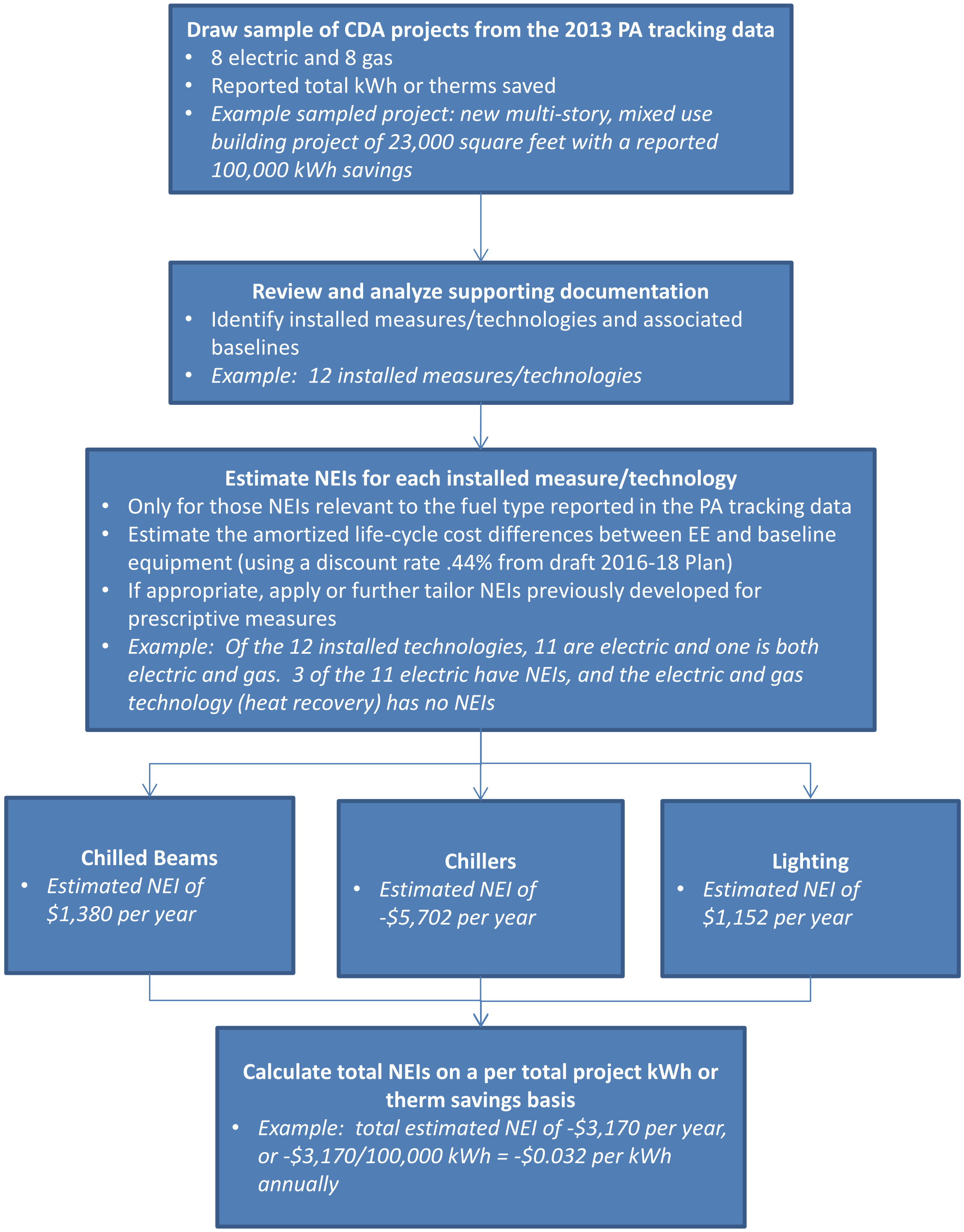
4. *Estimate NEBs for each line item separately* – Based upon the number, size, and other specifications for the actual equipment installed, we estimated the NPV of the life-cycle cost differences between the energy-efficient and baseline technologies for each line item identified in the paper documentation. Since many of the NEBs for these line items corresponded directly to their prescriptive counterparts, we used the same prescriptive-based NEB calculation formulas or specs developed previously. In this case, we added these performance based NEB calculations to the set of NEB formulas for the performance based measure. Further, we considered the combined operational cost impact of all line items for a sampled project, as some line items may have joint impacts on operational costs.
5. *Isolate NEBs to a single fuel type* – CDA projects reported in the electric and gas tracking data reported only savings associated with the respective fuel, and we were not able to readily determine whether the projects appeared in the other fuel type's program tracking records. Therefore, for each sampled project, we restricted the analysis to include NEBs associated with those line items that were relevant to the source program tracking database's fuel type. In other words, if the project record was identified from the gas program tracking database, we considered only line items that were relevant to gas measures (and gas savings). In our sample, none of the measures that affected both gas and electric savings (such as heat recovery or building shell) resulted in any quantifiable NEBs, so we did not have to determine how to split the NEBs between the electric and gas measures.
6. *Calculate the total NEB for each sampled project* – Next, we combined (summed) the NEBs for all the individual measures/technologies or line items associated with the relevant fuel type.
7. *Calculate NEB / kWh or therm for the measure category* – Finally*,* we calculated the ratio of NEB per kWh or per therm for each sample project and across all sampled projects.

Example of NEB Computations for Performance Path-Based Projects

Figure 2 illustrates how we calculated savings for one sample NC CDA project.

CDA project description (Example): The building is an approximately 23,000-square-foot, multi-story, mixed-use building for which the program claimed approximately 100,000 kWh electric savings. The program did not claim any gas savings.

Figure 2. Process for Estimating NEBs Resulting from Performance Path-Based Measure



Estimate NEB per unit of energy savings be measure

Once we estimated NEBs per unit of energy savings ($ per kWh or therm) for each sampled measure, we applied sample weights to calculate the estimated NEB per unit of energy savings for the group of measures represented by our sample.

New construction measure engineering analysis NEB results

The total annual value of NEBs for 2013 NC program participants that conducted "true" NC projects was roughly $488,122 per year, across the total population of 956 true NC measures installed in 2013, including 13 electric projects and 10 gas projects listed under the single performance path-based CDA measure category.[1] Table 2 provides a breakout of estimated NEBs by project track. The following discussion details the results of the engineering analysis. We first discuss the general results from the engineering analysis, and then discuss several special considerations in the analysis.

The results of the new construction NEB studies are presented in Table 2 below. For new construction measures, we provide NEB estimates for several measure categories even though they are not statistically significant at the 10% significance level or better.

- *Lighting* – NEBs associated with lighting consist largely of differences in replacement and maintenance costs associated with efficient bulbs lasting longer. There were additional benefits with lamp replacement when fewer efficient lamps were needed to provide the same lumens as the baseline lamp. These cost savings were specific to the lamp type relative to the baseline standard efficiency T8 lamp. Therefore, it was relatively straightforward to estimate NEBs by lamp type as well.
- *HVAC* – In a new construction setting, NEBs for HVAC measures often have offsetting positive and negative NEBs. For example, Centrifugal compressors require more maintenance than a screw, and a screw requires more than a scroll compressor. However, a magnetic bearing centrifugal compressor does not require oil and therefore offers a unique and valuable NEB by reducing oil changes, oil analysis, oil pump rebuilding, and oil heater/cooler maintenance.
- The CDA measure is an important part of the NC program and constitutes 18% of custom electric savings and 40% of custom gas savings. While a custom comprehensive project may contain both gas and electric saving technologies, we only consider the NEBs related to gas saving technologies for those projects recorded under the gas program, and NEBs related to electric saving technologies for those projects recorded under the electric program. We did not find statistically significant NEBs for the custom-comprehensive electric measures, but did find statistically significant NEBs for the custom-comprehensive gas measures. We recommend our estimate of -$.004/therm be used in the BC model for comprehensive gas measures, and do not recommend the NEB estimate for comprehensive electric measures be included.

[1] The annual value = ratio of $NEB/unit of energy savings by measure x 2013 annual energy savings for each measure.

Table 2. NEB results for New Construction measures[2]

Sample Category	Average Annual NEI per Measure	Lifetime Replacement NEI/ kWh	Operations and Maintenance NEI/ kWh	Overall NEI/kWh	90% CI Low	90% CI High	Statistically Significant?
Electric - Custom							
Comprehensive Design	$ 207	$ 0.002	$ (0.001)	**$ 0.001**	$ (0.007)	$ 0.009	0
Compressed Air	$ 1,155	$ 0	$ 0.026	**$ 0.026**	$ 0.002	$ 0.050	b
Commercial Kitchen	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0
HVAC	$ 330	$ 0.001	$ 0.001	**$ 0.001**	$ (0.002)	$ 0.005	a
Lighting	$ 320	$ 0.003	$ (0.000)	**$ 0.003**	$ (0.001)	$ 0.007	a
Motors	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0
Other	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0
Industrial Process	$ 3,990	$ 0.000	$ 0.013	**$ 0.013**	$ 0.004	$ 0.022	b
Refrigeration	$ 3,657	$ 0.003	$ 0.009	**$ 0.012**	$ 0.003	$ 0.021	b
Overall	**$ 1,063**	**$ 0.002**	**$ 0.004**	**$ 0.006**	**$ 0.002**	**$ 0.009**	**c**
Electric - Prescriptive							
Compressed Air	$ 1,717	$ 0	$ 0.038	**$ 0.038**	$ 0.033	$ 0.042	c
Commercial Kitchen	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0
HVAC	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0
Lighting	$ 757	$ 0.014	$ 0.007	**$ 0.020**	$ 0.013	$ 0.028	c
Motors	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0
Overall	**$ 522**	**$ 0.009**	**$ 0.006**	**$ 0.016**	**$ 0.010**	**$ 0.021**	**c**
Gas - Custom							
Building Shell	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0
Comprehensive Design	$ (117)	$ 0	$ (0.004)	**$ (0.004)**	$ (0.008)	$ 0.000	a
Boilers	$ (73)	$ 0	$ (0.006)	**$ (0.006)**	$ (0.013)	$ 0.001	a
Commercial Kitchen	$ 2,732	$ 0	$ 3.399	**$ 3.399**	$ 0.961	$ 5.836	b
HVAC/ Heat Recovery	$ 4	$ 0	$ 0.000	**$ 0.000**	$ (0.000)	$ 0.001	a
Other Gas Heating	$ 0	$ 0	$ 0	**$ 0**	$ 0	$ 0	0
Other	$ (277)	$ 0	$ (0.032)	**$ (0.032)**	$ (0.092)	$ 0.029	a
Industrial Process	$ 72	$ 0	$ 0.007	**$ 0.007**	$ (0.011)	$ 0.025	0
Overall	**$ (83)**	**$ 0**	**$ (0.005)**	**$ (0.005)**	**$ (0.008)**	**$ (0.001)**	**b**
Gas - Prescriptive							
Commercial Kitchen	$ 2,732	$ 0	$ 3.399	**$ 3.399**	$ 0.961	$ 5.836	b
Boilers	$ (137)	$ 0	$ (0.084)	**$ (0.084)**	$ (0.111)	$ (0.057)	c
HVAC/ Heat Recovery	$ 39	$ 0.327	$ (0.085)	**$ 0.242**	$ (0.174)	$ 0.657	a
Other Gas Heating	$ 17	$ 0	$ 0.053	**$ 0.053**	$ 0.043	$ 0.063	c
Overall	**$ 260**	**$ 0.011**	**$ 0.224**	**$ 0.235**	**$ (0.007)**	**$ 0.477**	**a**

Of interest in this breakout is the relatively large difference in NEBs between identical measure types in the custom and prescriptive programs. Using the program data, we identified that custom lighting projects tend to replace few higher-wattage bulbs (e.g., T-5 linear fluorescent) with an LED equivalent, whereas prescriptive projects tend to replace many lower wattage bulbs (T8) with an LED equivalent. This results in greater O&M savings per kWh for the prescriptive projects.

[2] a. Recommended, but not well determined ($.10 < p \leq .50$); b. Recommended, statistically significant at 90% confidence ($p \leq .10$); c. Recommended, statistically significant at 99% confidence ($p \leq .01$); 0: NEBs are determined to be negligible Not Recommended: $p > .50$)

Table 6. Lighting NEBs by Lamp Type

Measure Type	Measure Subtype	Ratio (NEB/kWh)	Statistically Significant?	2013 Weighted Annual NEB
Custom Lighting	LEDs	$ 0.009	No	$2,525
	Other Lighting	$ 0.001	No	$497
	Performance Lighting	$ 0.004	No	$4,670
Prescriptive Lighting	LEDs	$ 0.036	Yes	$256,838
	Performance Lighting	$ 0.017	No	$38,398
	T5 Lighting	$ (0.001)	Yes	($3,693)
	High Bay LEDs	$ 0.048	Yes	$41,331

Conclusions

Our analysis demonstrates that participant NEBs provide important indicators of the overall value proposition of EE programs and the measures they support. Positive NEBs can provide substantial benefits to program participants, thereby helping to justify the capital investment in EE technologies. Negative NEBs identify areas that program support may be required to offset annual maintenance charges, or suggest that program planners reallocate resources to measures with lower life-cycle costs that serve as barriers to implementing. Finally, program evaluators and regulatory agencies should seek including NEBs benefit cost tests used to assess the cost-effectiveness of energy programs as they provide clearer indication of the overall changes to economic efficiency resulting from EE programs.

Limitations

- Our research approach focused primarily on identifying annual NEBs. Consequently, the results may under estimate NEBs associated with one-time costs or benefits.
- The following factors may limit the applicability of NEB 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.
  - ✓ The mix of measures assumes C&I programs that are retrofits, which consisted of a mix of early replacement and replace on failure measures.
- The new construction NEB study was focused on operational cost changes only. Because the measures installed were new construction, we could not justify including productivity or revenue increases, as our analysis did not find such changes would occur from an engineering perspective. Further research is required to explore whether there are additional sources of NEBs.
- Significant program changes in terms of mix of measures, or favoring early replacement over replace on failure could make the NEB values from this study less applicable.

References

[i] Abdou, Marie, Noel Stevens and Anthony Davis. "Non-Energy Impacts Provide Powerful Marketing Tools for Energy Efficiency Programs." International Energy Program Evaluation Conference, Long Beach. Long Beach, CA. August 2015.

[ii] Final Report – Commercial and Industrial Non-Energy Impacts Study." Prepared for the Massachusetts Program Administrators by DNV KEMA and TetraTech. June 29, 2012.

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

[iv] Stevens, Noel, Kimberly Crossman, Pam Rathbun, Miriam Goldberg, and Ben Jones. "Non-energy impacts of C&I energy efficiency measures provide substantial program benefits above carbon reduction." International Energy Program Evaluation Conference, Chicago. 2013.

[v] See Endnote: iv. Combined heat and power provides one example of a measure with negative benefits.

[vi] Massachusetts Electric and Gas Program Administrators—C&I New Construction NEI Stage 2 Final Report. To be published Summer 2016.

[vii] Larsen, Peter, Charles Goldman, Donald Gilligan, and Terry E. Singer. "Incorporating Non-Energy Benefits into Energy Savings Performance Contracts." ACEEE Summer Study on Energy Efficiency in Buildings. 2012.

[viii] Dodge Players contains information on all known new construction and major renovation projects in the Commonwealth. http://construction.com/dodge/

[ix] Massachusetts Technical Reference Manual. D.P.U. 12-100 to D.P.U. 12-111 Three-Year Plan 2013-2015. October 31, 2012. Exhibit 1, Appendix N. Page 1 of 451. http://ma-eeac.org/wordpress/wp-content/uploads/TRM_PLAN_2013-15.pdf

[x] ASHRAE STANDARD ANSI/ASHRAE/IESNA Addendum to ANSI/ASHRAE/IESNA Standard 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating, Refrigerating. January. 2007. https://www.ashrae.org/standards-research--technology/standards-interpretations/interpretation-for-standard-90-1-2007

[xi] 2016 – 2018 Massachusetts Joint Statewide Three-Year Electric and Gas Energy Efficiency Plan. http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-DRAFT-Electric-Gas-Energy-Efficiency-Plan.pdf.