I Need to Know: Understanding Non-Energy Impacts for C&I Programs

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ABSTRACT

Understanding and monetizing non-energy impacts (NEIs) is increasingly important for program administrators in the face of rising energy efficiency targets, customer disengagement, and pressure to ensure cost-effective portfolios. While NEIs have historically been used for program applications and marketing, program administrators are increasingly including NEIs in program evaluation to provide a stream of benefits used in benefit-cost analysis (BCA). This increased interested in NEIs for BCA purposes has been exacerbated by pressures from stakeholders and policymakers surrounding the recent introduction in Massachusetts of ambitious greenhouse gas (GHG) emissions targets, which put the Energy Efficiency (EE) programs' role center stage. (EEA, 2021) By expanding the base of knowledge and updating or quantifying formerly perceived NEIs, Massachusetts Program Administrators (PAs) have more tools at their disposal to make the EE program a program to respond to the needs of the future.

In this paper, we present the results of a study to identify and monetize NEIs attributable to the PAs' C&I program measures in two categories: Operations and Maintenance (O&M) impacts and non-Operations and Maintenance (non-O&M) impacts.

Introduction

In 2020, the PAs completed a commercial and industrial (C&I) NEI scoping study that identified and prioritized future research for NEIs. (NMR, DNV, Three[3], 2020) The scoping study found that a significant portion of existing measures either lacked NEI values or had outdated ones. Later in 2020, in preparation for the next Massachusetts three-year energy efficiency plan, the PAs asked DNV to scope out a study to address these significant gaps. Not only were these NEIs deemed vital to BCA planning as part of the three-year plan, but the NEIs garnered new emphasis as a tool for PAs to meet new GHG targets in an equitable and balanced manner.

This paper details the results of that study. NEIs explored in this paper fall into two general categories: O&M impacts and non-O&M impacts. Non-O&M NEIs include the impacts of energy efficiency measures on product sales; non-sales revenues such as rent, licensing, and carbon credits; impacts on productivity; material/supply costs; non-O&M labor impacts; and product spoilage or waste. The non-O&M impacts examined in this study exclude health and safety impacts, which the PAs expect to address in a future study.[1] The research presented builds upon two prior C&I NEI studies conducted in Massachusetts and the NEI framework developed by NMR and DNV for Massachusetts. Below we include brief descriptions of these earlier studies:

- The 2012 C&I Retrofit NEI Study (2012 Study) employed an interview-based approach to capture NEIs for 2010 prescriptive and custom electric and gas retrofit measures across 12 mutually exclusive NEI

[1] The COVID-19 pandemic was a significant factor in the decision to delay measuring H&S NEIs. The study sponsors were concerned about contacting end users about sensitive health and safety issue during the pandemic and that impacts of the pandemic, such as reduced building occupancy and increased ventilation, might produce results that were not representative of a typical year.

categories. It found that roughly 80% of NEIs claimed by respondents were O&M cost savings. (Tetra Tech 2012)

- The 2016 C&I New Construction NEI Study employed an engineering-based life-cycle cost (LCC) estimation approach to provide O&M cost savings or increases attributable to some measures in the New Construction program (specifically, “true New Construction,” as opposed to the major retrofits). (DNV GL 2016)
- The 2018 Massachusetts NEI Framework Study assessed the merits of NEIs across the portfolio of C&I and residential programs and provided a roadmap for the PAs to use when they consider NEI research. The study found gaps in program offerings covered by prior NEI research and opportunities for new NEIs, such as H&S impacts. (Tetra Tech 2018)

Research Objectives

The research objectives of this study were to:

- Develop O&M NEIs values broadly across all C&I measures and programs
- Develop non-O&M NEI values (excluding health and safety NEIs) focusing on measures common to the small business programs offered by the PAs

The study was designed to produce:

- Updated O&M NEIs
- Additional O&M NEIs for new measures not previously claimed
- Identification of differences in O&M NEIs by event type, Replace-on-Failure/New Construction, or Early Replacement, considering the appropriate baseline treatment for each category
- Additional non-O&M NEIs with a focus on measures important to small business customers
- Information on the presence of H&S-related NEIs and the ability of vendors and end users to report information to support quantification

The results from this study are intended to inform measure BCA. They may also be used by program staff to help market the full value of energy efficiency improvements to end-use.

Methodology

The methods employed for identifying and measuring NEIs differed by type, O&M versus non-O&M. The differing approaches were selected to align with availability of data and understanding of NEIs for the two types of NEIs studied, based on prior research and experience. The primary difference in data collection for O&M and non-O&M was which market actors were interviewed. For O&M, we exclusively interviewed vendors, and for non-O&M we interviewed end-use customers. In addition, the Massachusetts PAs and EEAC representatives wanted a small business focus for the non-O&M NEI research, to support a need for more robust findings within this market segment. To that end, the non-O&M interviews focused on measures offered through the small business PA programs.

Estimating O&M NEIs

For O&M NEIs, we focused our data collection efforts on third-party data costing tools and interviews with vendors. We did not conduct any interviews with end-use customers to quantify and monetize O&M NEIs because end-use customers would not have the breadth of experience required to differentiate differences in high efficiency and standard efficiency equipment.

We set up lifetime O&M cost calculations based on annual O&M costs and equipment life for the base and efficient cases, got the costing parameters from third-party costing tools, then vetted those parameters with vendors.[2] The O&M estimation process included the following steps: 1) identify end-use categories and measures of interest, 2) set up NEI calculations as functions of key parameters, 3) identify parameters from libraries, 4) vet the parameters with IDIs, 5) calculate lifetime NEI per lifetime savings using the library parameters and using the IDI responses, 6) either accept the library-based values as confirmed by the IDIs, or replace them with an IDI-based value, following a set of decision principles.

The evaluation team began with a sample frame of vendors of energy-efficient equipment who were listed in the 2018 program tracking data. The team then enlisted the help of the Massachusetts PAs to supplement this initial list with additional vendor names and relied on the Massachusetts Energy Management System (EMS) Industry Standard Practice (ISP) study to provide additional EMS and Retrocommissioning (RCx) vendor contacts.

In several instances, a single equipment vendor had projects covering multiple measure categories. In such cases, the team limited the vendors to no more than two measure categories per interview. The team also gave priority in these interviews to the measure categories with the least number of vendors in the sample frame. The EMS/RCx and building shell measure categories were the highest priorities based on these criteria.

Estimating Non-O&M NEIs

To estimate non-O&M NEIs, we conducted IDIs with Small Business customer end-users to capture information on the incidence of non-O&M NEIs, the direction of the impacts, and metrics to quantify the impacts. For each measure the customer had installed, the interviewer asked whether their organization had experienced positive or negative NEIs related to the higher efficiency of the new equipment. For those that had, the interviewer attempted to collect quantitative information to support monetizing the NEI value. Interviewers first identified the source of any changes because of higher efficiency equipment and then sought to quantify the level of changes. Categories of non-energy impacts included changes in sales, administrative costs, product spoilage, productivity, supply costs, useful life of equipment, and employee downtime. Depending on which, if any, categories were identified as changed, interviewers asked follow-up questions to identify the level of changes in a metric appropriate to the category (ex. dollars for sales, years for equipment life, hours for downtime).

The evaluation team developed two sample frames for the non-O&M survey based on priority of the respondent. All eligible participants in the 2018 Small Business Initiative were included in the first sample frame (Priority 1). Once that sample frame was exhausted by the survey house, DNV provided a second sample frame from the 2018 tracking data with an extended population (Priority 2). The extended population comprised organizations that did not participate in the Small Business Initiative but installed similar measures through the program.

Measure Selection

Selecting energy-efficiency measures for the O&M NEIs was a two-step process. In the first step, a group of PA and EEAC representatives and the evaluation team members (the study Working Group) identified eight categories of energy-efficiency measures on which to focus the O&M NEI interviews: HVAC-electric, HVAC-natural gas, lighting controls, motors and drives, EMS/RCx-electric, EMS/RCx-natural gas, envelope-natural gas, and hot water-natural gas. A primary consideration in selecting these measures was their contribution to overall energy savings in the C&I program portfolio. Process was originally among these measure categories, but since many process measures use technologies similar to those in the other measure categories, the Working Group agreed to calculate process NEIs as a weighted average of directly assessed NEIs. Weights were set subjectively by the evaluation engineers familiar with the process measures in the program.

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[2] We conducted the in-depth interviews with equipment vendors in stages. Most interviews were completed between April and May 2021 by engineers with specialized knowledge of the technologies about which they were asking.

In the second step, the evaluation team reviewed the 2018 tracking data to determine on which specific measures within each of the measure categories the O&M NEI research should focus. The criteria the team used for selecting these measures included:

- Proportion of total energy savings: The evaluation team prioritized measures that accounted for a large percentage of the energy savings in the 2018 program tracking data.
- Applicability to other measures: The team also prioritized measures for which an NEI value in $/kWh or $/therm could reasonably be assumed to apply to other measures.
- Technological differences: The team considered the implications of the measure's technology for O&M costs. For example, the team treated water-cooled chillers > 300 tons and air-cooled chillers > 150 tons as separate measures, since we assumed the technological differences between these two measures would have O&M implications.

Baseline Framework

One of the study's research objectives was to provide NEI estimates for multiple event types: Replace on Failure (RoF), New Construction (NC), and Early Replacement (ER). Given that new equipment, regardless of efficiency and event type, may result in NEIs, it was important for the team to determine which NEIs were attributable to only efficient equipment and not simply to new equipment. This presented a special challenge for interviews given that end-use customers are generally familiar with the equipment they have in place (existing or new) and not with the characteristics of alternative equipment they did not choose. We found that NEIs associated with efficient vs. standard new equipment was best done with vendors whose experience is broader than end-use customers. This means that the distinction between efficient vs. standard new was more reliable for O&M than for non-O&M, since we interviewed vendors for O&M NEIs and end-use customers for non-O&M NEIs.

An additional challenge was that many of the energy efficiency measures were add-on measures, which are designed to improve the efficiency of existing equipment rather than replace it. Examples of add-on measures included Variable Frequency Drives (VFDs), EMS, RCx, and lighting controls. For non-O&M, this made it easier for end-users to identify NEIs associated with efficient measures because there was no standard efficiency. For O&M, since third-party cost libraries do not provide O&M costs with and without the add-on measure, we needed to rely exclusively on vendors for information on how O&M costs and lifetimes differed by presence of the add-on.

For O&M, to gather the best possible data on NEIs from equipment versus the baseline, it was essential to present vendors not only with a description of efficient equipment but also with the baseline, delineated by the event type. We shared data in a tabular form with vendors that compared energy-efficient measure and baseline equipment assumptions that the evaluation team used for various equipment add-on and replacement scenarios, for a sampling of measures explored. These assumptions were used to structure the cost streams. In the case of add-on measures, such as controls or insulation, the NEI is based on the difference in O&M cost streams between the affected equipment without the add-on versus with the add-on. Each baseline and efficient equipment type were accompanied by assumptions related to O&M costs, allowing for respondents to provide feedback on baseline and efficient equipment separately.

O&M NEI Calculations

Quantification and monetization of O&M NEIs was a somewhat complicated process requiring careful attention to various value streams and their frequency. Some O&M costs happen every few years instead of annually, creating spikes in O&M costs that can introduce high sensitivity to small changes in the calculation of the NEI cost streams. For example, if the baseline equipment had a measure life of nine years and the energy-efficient measure had a measure life of eleven years, with major maintenance occurring every five years, then the longer-lived energy-efficient measure would incur major maintenance costs in the tenth year that the shorter-lived baseline equipment would not.

To avoid these kinds of sensitivities, the evaluation team chose to levelize costs for major maintenance scenarios. Based on methodologies developed for other Massachusetts C&I studies, the evaluation team also levelized equipment replacement costs for cases in which the energy-efficient measures had longer measure lives than their baseline counterparts.

For a cost C that would be incurred every L years, the levelized annual cost LAC(C,l) is the annual accrual amount such that the NPV of a single cost C at year Y is the same as the NPV of a cost of LAC(C,L) incurred annually from Year Y to Year Y + L - 1. For example, a cost of $1,000 occurring every 10 years has a levelized annual cost of $101/year. The NPV of a 10-year stream of costs of $101 is the same as the NPV of a $1,000 cost in the first year of that stream. This calculation used a 0.21% discount rate.

Similarly, replacement costs required levelization across different scenarios because expected measure lives may vary by efficiency level. In some cases, the baseline equipment has a shorter effective useful life (EUL) than the efficient equipment, or in an ER case, the baseline equipment would be replaced during the timeframe of the efficient equipment's EUL. Rather than count a full replacement cost based on a difference of less than a full measure life, the levelized annual cost of replacement is calculated and applied annually only for the number of years by which the efficient EUL exceeds the baseline EUL.

On rare occasions, the efficient equipment has a measure life that is shorter than the baseline equipment. In such cases, the evaluation team wanted to count O&M costs only over the lifetime of the efficient equipment and did not want to count the next replacement cost of the efficient equipment. At the same time, the evaluation team wanted the NPV calculation to account for the fact that the baseline equipment would still have some years of life after the end of the efficient equipment lifetime.

We chose to address this by crediting the longer-lasting baseline equipment with the cost savings from avoided years of levelized replacement costs. For example, if the efficient equipment had an EUL of 20 years and the baseline equipment had an EUL of 23 years, the negative of the levelized annual replacement cost of the baseline equipment is counted for years 21 through 23 of the baseline equipment's measure life. No other costs are counted for these outyears.

For many add-on measures, the measure has the potential to extend the life of the affected equipment, but the add-on measure itself has a shorter life than the affected equipment. To capture the benefit of the longer equipment life within the lifetime of the add-on measure, the evaluation team calculated the levelized annual replacement cost with and without the add-on, and discounted both back to begin accruing in Year 1.

To reduce the spikes in O&M cost streams from major maintenance events, the evaluation team entered major maintenance costs on a levelized annual cost basis. The standard levelized cost would start to be counted in the first major maintenance cycle. For simplicity, the costs were made to accrue starting in year 1, with the standard levelized costs discounted back by the number of years of the major maintenance cycle. For example, if there was a $1,000 cost beginning in Year 11 and repeating every 10 years, the evaluation team instead assigned an annual cost of $99 starting in Year 1. This treatment was applied to all analysis cases. Finally, we assigned the O&M NEI values to be used in the benefit-cost ratio (BCR) Tool, based on the measure category, source, and program.

Non-O&M NEI Calculations

We developed non-O&M NEIs based on interviews with end users about the specific measures they had installed, which included heat pumps, chillers, refrigerator controls, and building envelope measures. The interviews asked whether the respondent had experienced positive or negative NEIs related to the higher efficiency of the new equipment in each of several specific categories. Respondents were first asked to provide

NEIs unprompted and were then prompted (as appropriate) about other NEIs that were not mentioned in their unprompted responses. For those that had experienced NEIs, the interview attempted to collect quantitative information to support monetizing the NEI value.

The evaluation team completed 53 interviews, along with 16 partially completed interviews. Because there were relatively few respondents providing monetized NEIs in this study, the results from this study were used to develop an update factor to apply to those from the larger-scale 2012 study to produce updated values with end-use granularity. Therefore, we do not present standalone small business NEI values. As noted, the COVID-19 pandemic made it difficult to reach the small business customers.

The non-O&M NEI estimation process involved the following steps:

- Determine end-use categories of interest in consultation with the PAs and EEAC
- Calculate an overall lifetime NEI per lifetime MMBTU across end uses and fuels, as well as across end uses and fuels, and across all non-OEM NEI categories
- Obtain from the 2012 study for each program (custom or prescriptive) and fuel (electric or gas) the following: 1) the percent of NEIs that were O&M, and 2) the overall NEI $/kWh and $/therm, by end use
- Estimate the 2012 non-O&M NEI for each program, fuel, and end use by multiplying the overall NEI $/kWh and $/therm values from the previous step by (100% - %O&M)
- For each end use-fuel combination u with results from the present study, convert the corresponding result from the 2012 study to $/MMBtu ($V_u$), and identify the total savings S_u, also converted to MMBtu, from the 2020 BCR tool. The savings totals exclude measures identified as custom, since the focus of the current Non-O&M study was on measures for small businesses, which are typically prescriptive.
- Calculate the savings-weighted average of the 2012 values, across the combinations that had corresponding data collected in the present study. This is equivalent to calculating the ratio of the sum of lifetime NEI value to the sum of lifetime savings.

$$R_{x2012} = \frac{\Sigma_u S_u V_u}{\Sigma_u S_u}$$

- Calculate the adjustment factor A as the ratio of the overall NEI per MMBtu value R_{ALL} from the present study to the corresponding value Rx_{2012}. Because the 2012 ratio is calculated only for the subset of similar measures, this gives an "apples-to apples" adjustment.

$$A = \frac{R_{ALL}}{R_{x2012}}$$

- Multiply each 2012 Non-O&M value by the adjustment factor A. This factor captures any inflation effects as well as other changes over the time from 2012 to 2020.
- Assign the non-O&M NEI values to be used in the BCR Tool, based on the measure category, source, and program

The team verified non-O&M NEIs as impacts attributable to the equipment's higher efficiency compared to the old equipment. We further categorized non-O&M costs and benefits into eight categories: 1) sales, 2) other revenues, 3) productivity, 4) other output or benefit, 5) materials/supply costs, 6) labor, 7) product spoilage or waste, and 8) other costs. While we asked about NEIs in these categories, we recognize that the same benefits might have been counted in more than one category. For each respondent with a monetizable NEI described, the NEI was monetized for the project as a whole.

Verifying Non-O&M NEIs: Participants claimed NEIs in various categories based on their understanding of cost breakdowns and non-O&M categories. We vetted whether the effect described was due to the efficiency improvement rather than just having new equipment and used additional survey response data to verify the presence of applicable non-O&M NEIs. For example, interviewers asked participants if impacts were due to equipment being new or higher efficiency. Similarly, interviewers recorded qualitative responses relevant to the nature of the equipment and claimed NEI(s), which proved useful in confirming the presence of NEIs.

To increase transparency and precision, DNV separated NEIs into two scenarios. The *more inclusive* scenario included the "borderline" cases if they had positive NEIs and excluded them if they had negative NEIs. Excluded NEIs were treated as 0. Only one respondent reported negative NEIs, so that this scenario included most of the borderline cases. The *less inclusive* scenario excluded borderline cases if the reported NEI was positive and included the negative NEI case.

Monetizing Non-O&M NEIs: For each reported NEI for which monetization was deemed possible, the team developed an annual dollar value, positive or negative, and calculated the NPV over the EUL. The team then identified the EUL for each measure type in the Massachusetts TRM. Next, using a discount rate of 0.21%, the team calculated the net present value of the NEI dollar stream over the course of the EUL. For the non-monetizable cases with confirmed non-zero NEI, it was assumed that the NEI per savings was the same as for the monetizable cases. Thus, the final NEI per savings value was the value for the monetizable cases multiplied by the fraction of lifetime savings that had non-zero NEIs, as detailed below.

Calculating Lifetime Non-O&M NEIs:

The analysis was initially conducted separately by fuel and end use. However, given the limited number of monetizable cases, the final results were based on a calculation across end uses and across fuels. The steps were as follows:

1. For each monetizable case j,
    a. Determine the lifetime NEI $ value $LNEI_j$ and the lifetime savings in kWh or therms, $LkWh_j$ or $Ltherms_j$, respectively
    b. Convert the kWh and therm lifetime savings to MMBtu $LMMBtu_j$.
2. Across the monetizable cases, sum the lifetime NEI and sum the lifetime MMbtu savings, and calculate the ratio summed NEI to summed savings. This is the monetizable ratio R_M:
$$R_M = \frac{\Sigma_j LNEI_j}{\Sigma_j LMMBtu_j}$$
3. Calculate the ratio of savings of projects with a non-zero NEI to the sum of all projects with collected data. This is the non-zero NEI fraction F.
$$F = \frac{\Sigma_j \mathrm{I}_j \, LMMBtu_j}{\Sigma_j \, LMMBtu_j}$$
where I_j = 0/1 indicator for project j having a non-zero NEI.
4. Calculate the overall NEI per savings as the product of the monetizable ratio R_M and the non-zero NEI fraction F:
$$R_{ALL} = F \, R_M$$
5. Convert the overall ratio back to $ per kWh and $ per therm.

Additional NEIs Identified by Market Actors

In addition to asking equipment vendors to estimate differences in O&M costs between energy-efficient and baseline measures, the evaluation team also asked the vendors about other possible NEIs of energy-efficient measures besides O&M. The team did not ask the vendors to monetize these benefits due to the length of the interview guide and the inherent difficulty of monetizing impacts across the numerous projects they work on every year. The table below shows the non-O&M NEIs they identified. These NEIs may be of interest to other authors wishing to understand and monetize NEI value streams.

Non-O&M NEIs Identified by Vendors

Measure Category	Non-O&M Benefits	Non-O&M Negative Impacts
RCx/EMS	Extending the life of the controlled equipment, improved thermal comfort, improved air quality, improved productivity, reduced product spoilage/waste, increased sales/revenue, and reduced material/supply costs	
Building envelope	Extending the life of HVAC equipment, improved thermal comfort, reduced product spoilage/waste, improved air quality, increased sales/revenue, improved productivity, and increased building value	
Hot water	Reducing noise, increasing worker safety	
Lighting controls	Extending the life of lighting equipment, customizing lighting use, providing information on building occupancy patterns	Higher first cost, learning curve for facility staff
Motors/drives	Extending the life of pumps/motors, reducing noise	

Conclusions

There were some general patterns among the factors/drivers determining the directionality and magnitude of the O&M NEIs.

- *Add-on equipment tended to extend the life of the impacted equipment:* Many equipment vendors attributed longer measure lives to equipment impacted by add-on equipment such as VFDs, lighting controls, EMS, and RCx. This increased NEIs for most of these add-on measures compared to the baseline scenarios (e.g., no controls) since the uncontrolled equipment incurred equipment replacement costs sooner.
- *O&M costs tended to be higher for energy-efficient measures with more complicated technologies:* Many equipment vendors attributed higher O&M costs for energy-efficient measures with more complicated technologies compared to their baseline counterparts. For example, they attributed higher O&M costs to high efficiency boilers because they were more complicated, with more controls and heat recovery systems.
- Often the impacts of longer measure lives, but higher O&M costs, in the efficient scenarios led to NEI values that converged towards zero. While the longer measure lives drove NEIs for energy-efficient measures in a positive direction, these were often partially or completely offset by the negative direction caused by the higher O&M costs attributed to them. However, these lower O&M NEIs values were often offset by higher positive non-O&M values for these same measures, leading to a positive overall NEI adjustment.
- Control technologies tended to have the highest NEIs because they were credited with both extending equipment life and reducing O&M costs. This was the case for measures such as lighting controls, EMS, and RCx, where controls could both reduce the operating hours of the controlled equipment and provide end users with increased visibility on the performance of this equipment, so malfunctioning equipment could be detected sooner.

- The non-O&M impacts examined in this study do not include health and safety (H&S) impacts; however, a future study plans a detailed examination of H&S NEIs, which will include monetization of any impacts.

The complete results and specific NEIs produced by the research are available in the full report. The table shows that in over 80 percent of cases, the NEI was derived from the vendor interviews. (DNV 2021)

Figure 1 below provide an overview of the results for O&M NEIs. Figure 2 provides an overview of the results for non-O&M NEIs. As noted, add-on measures such as EMS, lighting controls, and RCx have higher O&M NEIs because they both extend equipment life and reduce long-term maintenance costs by giving building owners quicker notification of malfunctioning equipment. In contrast, HVAC gas measures tend to have negative NEIs because the energy-efficient equipment tends to be more complicated (e.g., boilers with sophisticated controls) leading to higher O&M costs. Measures such as HVAC and building envelope have higher non-O&M NEIs because they improve building comfort, which can cause increased sales from customers and increased productivity from workers.

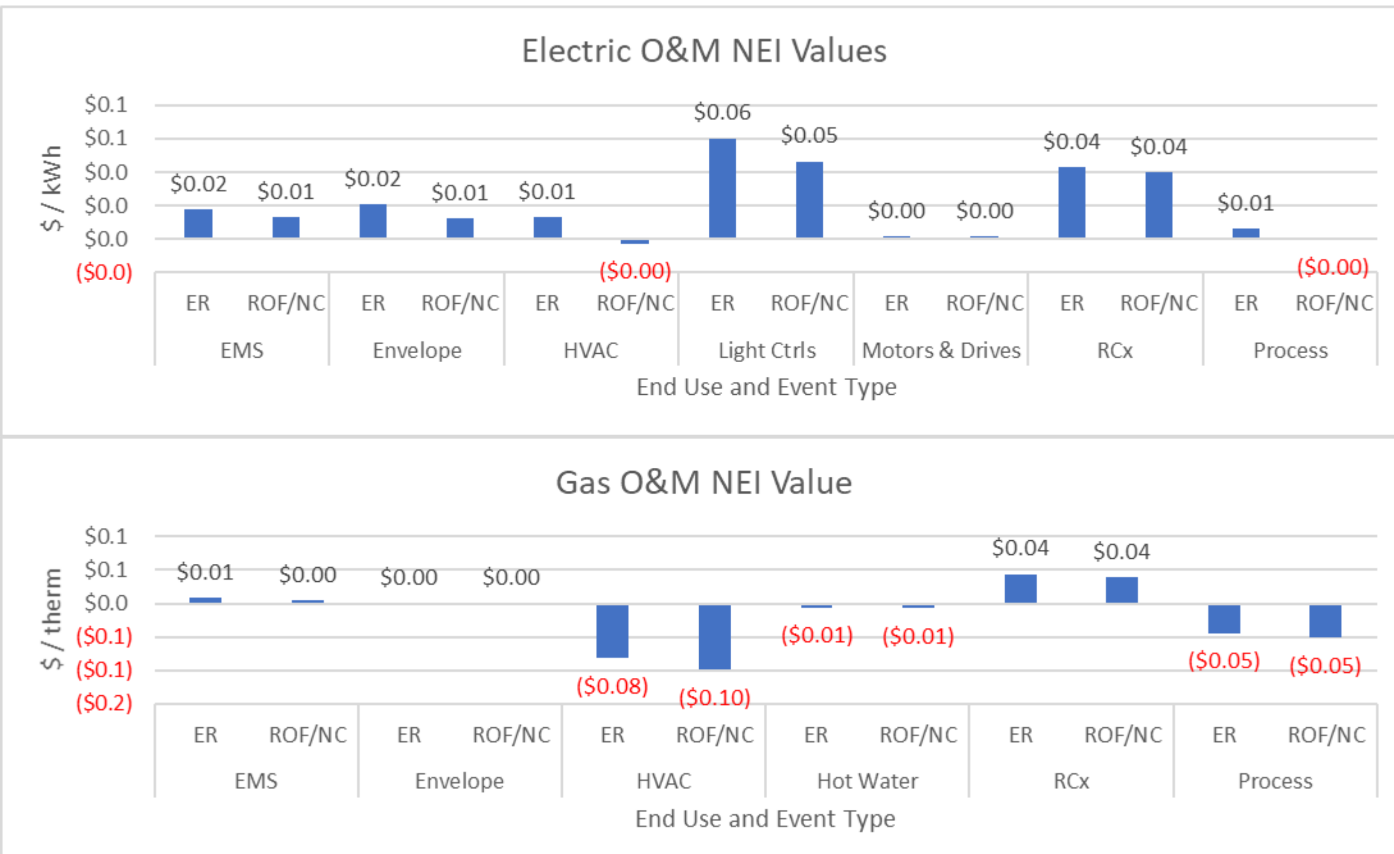

Figure 1 O&M NEI values by fuel type, end use, and event type[3]

[3] ER – Early Replacement; ROF – Replace on Failure; NC – New Construction; EMS – Energy Management Systems; RCx - Retrocommissioning

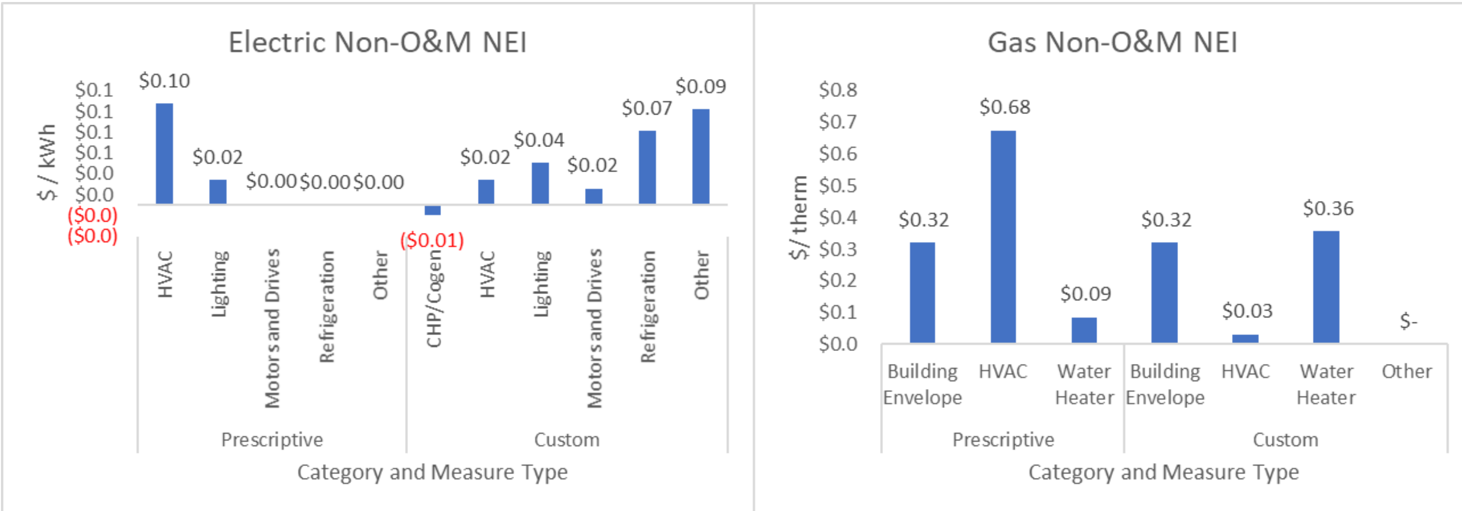

Figure 2 Non-O&M NEI values by fuel type, program category, and measure type

Key Considerations

- We found that estimating NEIs associated with efficient vs. standard new equipment, especially O&M NEIs, worked well when interviewing vendors who understood the equipment. Vendors had experience with a much broader range of projects than the end-use customers, and while end users could identify NEIs from the energy-efficient equipment they purchased, it was harder for them to do so for equipment they did not purchase – e.g., the less efficient baseline equipment. It was therefore difficult for them to distinguish NEIs that were due to equipment being efficient vs. just being new, which required the evaluator interviews to probe more deeply for these differences. Finally, fairly comparing the relative O&M costs of different equipment choices may only be possible over longer periods of time, and vendors would best have this knowledge of long-term O&M impacts.
- While vendors appeared, in most cases, to be familiar with the true O&M costs of the equipment they sell, we periodically enlisted senior engineers to conduct "reality checks" on any O&M cost estimates that seemed unreasonable. We chose to use trimmed means to help neutralize the impacts of extreme outlier estimates. In addition, it is important to match the target vendor group with the type of equipment likely to see O&M NEI impacts from the energy-efficient equipment. While we were successful in most cases, building envelope measures proved more difficult. This was because the O&M benefits for adding building insulation were mostly impacting the HVAC equipment and the insulation contractors we interviewed did not have as much knowledge about HVAC equipment O&M costs as HVAC contractors would have.
- Vendor alignment and agreement with O&M cost values from third-party costing tools varied by measure category. This indicates that the data collection approach was robust enough to elicit differing responses from vendors and not simply provide a blessing to existing values presented during interviews. In some cases, the vendors were able to verify and add credibility to the initial O&M cost values from third-party costing tools—in these cases we recommended adoption of the initial values. However, in other cases, the vendors provided different values suggesting a need to shift from third-party tools and vendor revised values were used to established O&M values.

- The non-O&M values derived from primary research as part of this study have the advantage of recency, but the disadvantage of smaller sample sizes due to the difficulties of data collection during the COVID-19 pandemic. The values from the 2012 study have the advantage of larger sample sizes, but the deficiency of being nearly decade-old data. Considering the different advantages and disadvantages of these two studies, it is prudent to use non-O&M estimates that combine values from the two studies.
- Getting customers to quantify non-O&M impacts can be challenging, but we found that it's often possible to get enough information on quantitative changes to monetize. Future research should include more open-ended questions discerning overall project impacts to compliment existing prescriptive questions targeting specific NEIs.
- Despite success with data collection, during data analysis it became clear that interviews would have benefited from inclusion of questions designed to document the rationale and mechanisms for differences in O&M costs between baseline and efficient equipment and O&M values that differed from third-party costing libraries. The current study did eventually collect information on the reasoning and mechanisms for these O&M cost estimates, but it did not do so in the initial vendor interviews. This lack of explanatory information in the early interviews made it difficult for the evaluation team to understand O&M estimates from the vendors that seemed counterintuitive.
- While the study methods probed for both positive and negative NEIs, and found both, customers predominantly reported positive non-O&M NEIs, even with the more restrictive screening used to ensure the impacts were efficiency related. Likewise, O&M lifecycle cost impacts were on balance positive for most, though not all, measure categories.

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