Estimation of Non-Energy Impacts from Energy Efficiency

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ABSTRACT

Non-Energy Impacts (NEIs) are an increasingly important area of research, as states and utilities across the country begin to incorporate NEIs into cost-effectiveness testing to justify increased funding for the energy efficiency programs. Recent literature reviews have found that more primary research is needed to assess and monetize these impacts. We conducted an evaluation of the participant NEIs associated with a Northeastern natural gas utility's residential market-rate energy efficiency programs and with a Northeastern electric and gas utility's low-income energy efficiency program. We surveyed participants about their perceived changes in winter comfort, summer comfort, safety, health, and noise to monetize each NEI and assess how the estimates varied with measure installations. The research found that NEI estimates varied dramatically between valuation methods. This paper reviews the various valuation methods, how the results vary across the methods, how the results differ depending on energy efficiency measures, and how the results differ between the residential market-rate and low-income programs. We recommend additional research on NEIs including cognitive interviewing and testing how the questions are framed to develop a better understanding of how NEIs should be valued.

Introduction

Residential retrofit programs provide rebates, incentives, and financing to support home energy efficiency improvements. While these programs help participants to reduce their energy usage and their energy costs, energy efficiency programs have also been shown to have additional benefits for participants, including improved comfort, health, and safety. These additional benefits are known as Non-Energy Impacts (NEIs). The purpose of this report is to analyze various methods for estimating and monetizing residential energy efficiency NEIs, and to recommend values for these benefits.

The goals of the NEI analysis were as follows.

- Apply several methodologies to measure the value of the NEIs, with information derived from participant surveys, program data, and billing data.
- Compare the values that result from the various NEI estimation methods.
- Develop a best estimate of the NEI values using all available information.

The NEI literature extends back for a few decades, but there are many challenges with the research. While there are hundreds of reports that cover NEIs from energy efficiency programs, many are dated, and most do not calculate benefits that are specific to the program and jurisdiction studied. Many references are only literature reviews, and even those that do quantify the benefits usually utilize estimates that were previously calculated in prior research. Most that reference previous research do not provide an assessment of the accuracy of the estimates or the

suitability for the population being studied. Even more challenging, papers point to previous studies (and those point to previous analyses) that do not provide adequate documentation of the research methodology used to estimate the NEIs.

This study aims to overcome several of these issues with the following approach.

- A survey conducted with participants in the program that is being studied.
- Rigorous sample design, implementation, weighting, and analysis.
- High survey response rates.
- Transparency regarding methods, potential issues, and limitations.

This study focused on the NEIs that accrue to residential energy efficiency program participants. It does not assess societal NEIs such as economic, environmental, and infrastructure impacts, nor does it assess utility NEIs such as reductions in arrearage carrying costs and collections expenses.

Information Sources

The study used several different data sources to develop the NEI estimates.

- Program Data: We analyzed data from the market rate and low-income energy efficiency programs to develop a sample frame and select a stratified sample of 2019 participants for each NEI survey.[1]
- Participant Survey: We conducted mixed mode web/telephone surveys with participants to collect information on perceptions of energy savings and the NEIs.
- Energy Usage: We analyzed energy usage data to estimate the change in electric and natural gas consumption that resulted from program participation.
- Energy Bills: We analyzed energy bill data to estimate the change in energy costs that resulted from program participation.

Usage Impacts

Many NEIs are related to the usage reduction impacts and some NEI valuation methods compare NEI value to energy cost reductions. Therefore, it is important to understand the actual program impacts on energy usage and on energy cost when assessing NEI valuations. This study included an analysis of the impact of the energy efficiency programs on natural gas consumption for 2019 participants for the market-rate program and on electric and natural gas usage for 2019 participants for the low-income program.

Energy usage was analyzed for the year prior to the audit visit and the year after service delivery was completed. The analysis included as close to a full year of pre- and post-treatment data as possible. Customers were included in the analysis if their pre- and post-usage data each spanned between 270 and 390 days. After these eliminations, we included the following customers in the analysis.

[1] The study was sponsored by APPRISE. The program sponsors remain anonymous for this study, so specific details on the programs are not provided.

- For the residential, market-rate program, we included 65 to 83 percent of the treatment group and 86 percent of the comparison group.[2]
- For the low-income program, we included 52 to 82 percent of the treatment group and 74 to 92 percent of the comparison group.

Usage data were weather-normalized in the pre- and post-usage period to ensure that changes in energy usage were not due to changes in weather. The key findings from the market-rate analysis are summarized below.

- Participants with only a thermostat installed and participants with only a water heater replaced with a new energy efficient model had statistically insignificant net savings values.
- Heating system replacement participants (replacing a gas furnace or boiler with a new high-efficiency model) had mean annual net savings of 39 Therms, or 3.1 percent of pre-treatment usage.[3]
- Home Performance with Energy Star (HPwES) participants (with insulation and air sealing work completed) had mean annual net savings of 202 Therms, or 16.8 percent of pre-treatment usage.[4]

The key findings from the low-income usage analysis are summarized below.

- Baseload jobs (which included refrigerators, lighting, and smart strips) had average net savings of 817 kWh, or 7.9 percent of pre-treatment usage.[5]
- Electric heating jobs (which include replacement with heat pumps or resistance heating) had average net savings of 1,449 kWh, or 7.7 percent of pre-treatment usage.[6]
- Gas heating jobs (replacement of current system with new high-efficiency model) had average net savings of 43 ccf (hundreds of cubic feet), or 4.2 percent of pre-treatment usage.[7]
- Net savings for the electric baseload group were much higher among the subgroup of participants who responded to the survey. Among electric heating jobs and gas heating jobs, net savings for survey respondents were comparable to the full group of program participants included in the usage analysis.

Bill Analysis

Billing data were analyzed for the year prior to the audit and for the year after service delivery was completed (2018 through 2020 data). Because the billing data cannot be weather-normalized and bills vary significantly over the year for participants who are not on budget billing, we required a full 11 months of charges in the pre- and post-participation periods to

[2] Attrition differed across the participant measure groups. This information is provided as reference, but not used in the final NEI analysis values, so additional information on the usage analysis is not provided to keep this paper's length within ACEEE's specifications.
[3] Statistically significant at the 99 percent level.
[4] Statistically significant at the 99 percent level.
[5] Statistically significant at the 99 percent level.
[6] Statistically significant at the 99 percent level.
[7] Statistically significant at the 95 percent level.

include the participants in the analysis. After these eliminations, we included the following customers in the analysis.

- For the residential, market-rate program, we included 64 to 82 percent of the treatment group and 84 percent of the comparison group.
- For the low-income program, we included 42 to 78 percent of the treatment group and we did not have a comparison group available for analysis.

The key findings from this analysis for the market-rate program are summarized below.

- Participants who received HPwES services had the largest reduction in natural gas costs. These participants reduced their annual natural gas charges by $68 on average, relative to the comparison group.[8]
- Participants in the heating system group reduced their annual bill amount by $9 on average, relative to the comparison group.[9]
- After accounting for the comparison group, the bill reductions for thermostat only participants and water heater only participants were not statistically significant.

The key findings from the bill analysis for the low-income participants are summarized below.[10]

- Among all electric baseload participants, total charges declined by $63 on average, or 6.4 percent of pre-treatment charges, following the program services. Among electric baseload participants who responded to the survey, the decline in charges was higher, at 9.3 percent of pre-treatment charges.[11]
- Among participants with air sealing and/or insulation measures but no HVAC measures, total charges declined by $33 on average, or 2.1 percent of pre-treatment charges. Survey respondents in the air sealing and/or insulation with no HVAC measures group saw a similar decline of 1.7 percent.[12]
- Among participants with HVAC measures, total charges declined by $32 on average, or 2.2 percent of pre-treatment charges, following the program services. However, among the subgroup of participants who comprised the survey respondents in the HVAC group, energy charges increased by $61, or 7.1 percent of pre-treatment charges.[13]

NEI Analysis

Non-Energy Impacts were estimated based on responses from a survey of program participants in the market-rate program and in the low-income program. Three different

[8] Statistically significant at the 99 percent level.
[9] Statistically significant at the 90 percent level.
[10] The survey respondents are a subset of those included in the usage analysis. Because of the small sample size, there is variability between the estimate for this subgroup and the full population that was analyzed.
[11] Statistically significant at the 99 percent level.
[12] Not statistically significant.
[13] Not statistically significant.

approaches that have been cited in the literature (additional details included later in the paper) were used to produce estimates.[14]

- Contingent Valuation (CV): Respondents reported a dollar value of the benefit.
- Direct Scaling (DS): Respondents reported a value for the benefit as a percent of the energy savings they experienced.
- Labeled Magnitude Scaling (LMS): Respondents valued the benefit as more or less valuable than the energy savings they experienced. These responses were then converted to a numeric multiplier.

Participant Survey

APPRISE conducted surveys with 393 2019 market-rate participants and 258 2019 low-income program participants. The survey questions addressed participants' perceived energy savings, NEI valuations, and relative valuations of the NEIs compared to energy savings.

Each survey (one for the market-rate program and one for the low-income program) utilized a mixed mode phone/web approach for the random sample of program participants selected for inclusion.

- The cooperation rate, the completion rate for market-rate participants who were contacted and who were eligible for the survey, was 88 percent.
- The cooperation rate for low-income participants was 87 percent.
- The response rate, the percent of eligible respondents who completed the survey, for market-rate participants was 67 percent.
- The response rate for low-income participants was 60 percent.

The following specific sequence of questions was asked for each NEI to provide data for the NEI value calculations. NEIs addressed in the study were winter comfort, summer comfort, safety, health, and noise.

- "Have you noticed a change in your home comfort in the winter since the energy efficiency work? Is your home now much more comfortable, somewhat more comfortable, no change, somewhat less comfortable, or much less comfortable?" (If no change, none of the other questions were asked.)
- "Think about the positive or negative value you experienced from this change in winter comfort — would you say it is more value, less value, or the same value to you as any possible energy savings you may have received from the program?"
- "Could you put a positive or negative dollar value on the change in winter comfort?"
- "What is that dollar value from the change in winter comfort? This question is asking how valuable the change in winter comfort is to you in dollars."
- "How does the dollar value from the change in winter comfort compare to the energy savings — 10% of energy savings, 20%, 30%, etc.? This question is asking how the dollar value from the change in comfort compares to the energy savings. For example, if

[14] These are the various ways to calculate NEBs. Additional information on each method and citations are provided later in the paper.

it was half as valuable you would choose 50%, if it was just as valuable you would choose 100%."

Questions for the other NEIs were the same as the questions listed below with minor changes, such as "Have you noticed a change in the noise level in your home since the energy efficiency work? Is your home much less noisy, somewhat less noisy, no change, somewhat noisier, or much noisier." [15]

There was considerable variation in the percent of respondents who provided data for each question as opposed to answering "Don't Know". Therefore, weights were developed for each individual survey question based on the data available for that question, and the applicable set of weights differed based on the valuation method and the NEI.

Contingent Valuation

The Contingent Valuation (CV) method asks participants to estimate the value of each impact in dollar terms. In the NEI survey, respondents were asked to provide a positive or negative dollar value that represented how valuable the NEI was to them. To obtain the respondent's estimated value of safety, for example, we asked the following questions.

- "Could you put a positive or negative dollar value on the change in safety?"
- (If yes) "What is that dollar value from the change in safety?"

This method is useful because it provides a specific dollar value for each benefit and the values can be easily compared between NEIs (Skumatz 2014). However, there is evidence in the literature that this approach leads to inflated values compared to the values obtained by scaling methods where the respondent is asked to compare the impact to a known dollar value (Horowitz and McConnell 2003). The CV method also suffers from known inconsistencies wherein valuations differ significantly based on the context and the specific questions asked (Hausman 2012). The most important of these is referred to as the "scope" problem, where contingent valuations fail to scale reasonably with the quantity of a good. An illustrative example is as follows: a respondent is asked about their willingness to pay to clean up one lake, and then asked about their willingness to pay to clean up five lakes, including the one asked about individually, and the respondent offers nearly identical dollar values to the two questions (Diamond and Hausman 1994).

The top values for the residential market-rate NEI survey responses were extreme outliers, so for each NEI we removed the top two percent of responses, similar to methods used in the literature (Skumatz 2002). Values that were excluded from the residential market-rate analysis ranged from a $500 value associated with the improvement in noise level to a one billion dollar value associated with the improvement in summer comfort. High end values that were excluded from the low-income program analysis ranged from $10,000 to three million dollars and low end values that were excluded ranged from negative $2,500 to zero dollars. After excluding these values, we computed the weighted average dollar value.

A key limitation of CV is that it is difficult for respondents to assign a dollar value to these impacts. Asking respondents to put a dollar value on NEIs may seem too hypothetical or

[15] Questions listed below are only the NEI survey questions. Additional questions were included in the participant survey for other aspects of the analysis.

arbitrary, and respondents might not consider the true value of the impact (Skumatz and Gardner 2006). In the residential market-rate program, an average of 22 percent of survey respondents said they experienced a change and provided a dollar estimate. In the low-income program, an average of 17 percent did so. Many respondents said they experienced no change in the NEIs studied, so the value was assigned to be $0.

Direct Scaling

The Direct Scaling (DS) method asks respondents to report the value of the NEI as a percentage of energy savings. A review of the literature shows that this approach often yields more consistent responses than the CV method (Clendenning et al. 2012). In some instances, researchers preferred the DS method to Labeled Magnitude Scaling because DS does not require the translation of qualitative data to quantitative data (Barket et al. 2006).

However, participants are sometimes confused by the questions used in the DS method. For example, the survey asked, "[h]ow does the dollar value from the change in winter comfort compare to the energy savings — ten percent of energy savings, 20 percent, 30 percent, etc.?", with response options ranging from zero to 100 percent. Respondents were confused by this question, so a clarifying sentence was added: "For example, if it was half as valuable you would choose 50 percent, if it was just as valuable you would choose 100 percent."

In the literature, surveys using this method typically allowed respondents to provide a percent over 100 where the NEI was of greater value than the energy savings (Fuchs, Skumatz, and Ellefsen 2004), but this survey confined responses to 100 percent or less. While our approach differs from the literature, we felt that restricting the valuation to a maximum value equal to that of the energy savings may result in more reasonable NEI estimates. We might reconsider that approach in future studies.

Because the DS method only collects a valuation in comparison to energy savings, it is necessary to also develop an estimate of energy savings. Two different natural gas bill savings values were used in this analysis. The first value was derived from the following survey question that was asked of all respondents.

- "What would you estimate the change in your annual natural gas bill was compared to the year before you received the program services?" [16]

The second value was developed from an analysis of the change in actual energy bills from the year prior to the treatment to the year following the treatment. We used the gross change in bills, because this is the actual change in energy costs that the respondent experienced (although the net change, where a comparison group is available, is a better estimate of the actual impact of the program). While the estimated change in the bill is a direct measurement, the participant's estimate of bill savings is actually what they use to value the NEI when asked about their valuation.

Table 1 compares the distribution of reported and actual bill savings by participant group for the residential market-rate program. In each participant group, the median and 25th percentile were higher for the actual savings than for the reported bill savings. However, some heating system participants and HPwES participants reported extraordinarily high savings values, which causes the overall mean savings to be higher for the reported than for the actual. In fact, 25

[16] Additional questions were asked to adjust for changes due to the COVID-19 Pandemic.

percent of HPwES participants who reported bill savings estimated annual savings values greater than $600.

Table 1. Market-rate distribution of reported and actual bill savings by participant group

Participant Group	Bill Savings	#[17]	Distribution of Values					
			Mean	Min	P25	Median	P75	Max
Thermostat Only	Reported	54	$4	-$456	$0	$0	$15	$300
	Actual	79	$41	-$221	$20	$40	$70	$183
Water Heater Only	Reported	38	$33	-$240	$0	$0	$0	$600
	Actual	67	$27	-$155	$5	$30	$52	$193
Heating System	Reported	46	$233	-$140	$0	$40	$240	$1,700
	Actual	65	$57	-$233	$13	$51	$92	$499
HPwES	Reported	42	$313	$0	$0	$100	$600	$1,250
	Actual	89	$106	-$107	$63	$108	$156	$260
Overall	Reported	180	$195	-$456	$0	$10	$240	$1,700
	Actual	300	$58	-$233	$14	$51	$92	$499

Table 2 compares the distribution of reported and actual bill savings by participant group for the low-income program. In each participant group, the 25th percentile was negative for the actual savings and $0 for the reported bill savings. For HVAC participants, the median reported savings were much higher than actual savings.

For each group, the mean reported savings were significantly higher than the mean actual savings. The difference was largest for HVAC participants.

For electric baseload participants, there were an equal number with reported and actual bill savings (although these were not the same respondents). For the other participant groups, there were fewer participants with actual bill savings.

The overall differences between reported and actual savings were similar whether the comparison was made for all participants, or only for those with data for both reported and actual savings.

Table 2. Low-income distribution of reported and actual bill savings by participant group

Participant Group	Bill Savings		#	Distribution of Values					
				Mean	Min	P25	Median	P75	Max
Electric Baseload	All participants	Reported	54	$154	-$2,280	$0	$40	$300	$3,000
		Actual	54	$80	-$711	-$91	$36	$257	$1,151
	Participants w/ data for both	Reported	31	$84	-$2,280	$0	$0	$240	$3,000
		Actual	31	$48	-$711	-$91	$54	$168	$772

[17] Refers to the number of respondents.

Participant Group	Bill Savings		#	Distribution of Values					
				Mean	Min	P25	Median	P75	Max
Air Sealing and Insulation	All participants	Reported	59	$255	-$1,800	$0	$120	$500	$2,800
		Actual	30	$106	-$669	-$126	$14	$161	$2,812
	Participants w/ data for both	Reported	23	$230	-$1,200	$0	$10	$500	$1,200
		Actual	23	$122	-$669	-$153	$15	$170	$2,812
HVAC	All participants	Reported	59	$310	-$2,760	$0	$20	$600	$3,000
		Actual	23	-$82	-$1,202	-$379	-$72	$346	$504
	Participants w/ data for both	Reported	16	$488	-$1,200	$0	$240	$810	$2,124
		Actual	16	-$32	-$799	-$411	$30	$359	$504
Overall	All participants	Reported	172	$242	-$2,760	$0	$80	$420	$3,000
		Actual	107	$52	-$1,202	-$143	$28	$211	$2,812
	Participants w/ data for both	Reported	70	$224	-$2,280	$0	$10	$360	$3,000
		Actual	70	$54	-$799	-$143	$39	$187	$2,812

Labeled Magnitude Scaling

Labeled Magnitude Scaling (LMS) was originally developed to study perceptual differences, and has typically been used to compare taste, touch, temperature, and other sensations. In this literature, the LMS scale is usually a continuous magnitude scale, with subjective labels used as anchors. Typical labels are “weak”, “moderate”, “strong”, and “very strong”. The maximum on the scale is the strongest imaginable sensation (Green, Shaffer, and Gilmore 1993).

LMS was adapted to the valuation of NEIs, but the approach has important differences from the way LMS was used outside the NEI literature. The NEI studies use relational questions for LMS, where respondents report how they value an NEI relative to their bill savings. NEI studies do not use a continuous response scale, but instead have respondents answer a question categorically, and then use a direct scaling response to associate values with the qualitative answers (Pearson and Skumatz 2002).

Labeled Magnitude Scaling (LMS) asked respondents to answer the following question.

- “Think about the positive or negative value you experienced from this change in [NEI area] — would you say it is more value, less value, or the same value to you as any possible energy savings you may have received from the program?”

These qualitative answers are assigned corresponding scalar values to calculate the resulting NEI valuation.

This question may be easier for participants to answer than the DS question because it uses word-based comparisons such as “more” or “less” valuable. It is also easier to answer than the open-ended dollar-value questions. Researchers have used the LMS method in conjunction with the DS Method to create an approach for analyzing NEIs that is more straightforward for survey respondents (Amann 2006).

To translate the qualitative responses into scaled dollar values, one or both of the following methods is used.

- A "within-sample" labeled magnitude scale is constructed based on the qualitative responses and the percentage values for the DS question. For instance, studies used the average of the percentage values for those respondents who gave the "much more valuable" response.
- Researchers use a set of ex ante LMS multipliers derived from earlier studies. However, many of the existing studies do not report the multiplier values used and instead simply state that the qualitative value responses were translated to dollar values "[u]sing previous research (Rosenbaum et al. 2012)."

Table 3 summarizes studies that used the LMS method. Based on a thorough review of the publicly available literature, the only NEI analysis that provided the LMS multiplier values used was the Pacific Northwest National Laboratory (PNNL) study conducted by Ledbetter et al (2019). Most studies in this area derived the scalar values from their own survey results and did not report the specific values.

Table 3. Labeled magnitude scaling literature review

Study	Objective	Scale	Source of Scalar Values
Skumatz (2002)	Assess NEIs associated with a residential weatherization assistance program in CT	5-point scale	Unreported survey results
Fuchs, Skumatz, and Ellefsen (2004)	Assess NEIs associated with ENERGY STAR measures in the New York Energy $mart Program.	11-point scale	Unreported survey results
Lim, Wood, and Green (2009)	Develop a labeled hedonic scale for sensations by quantifying the semantic values of terms used to describe liking and disliking of sensations.	9-point scale	Sensation ratings from 49 human subjects. Scale values from -100 to 100 assigned to five positive and five negative descriptors.
NMR Group (2016)	Assess NEIs associated with a home energy efficiency program in CT	5-point scale	Unreported survey results. (One multiplier of 1.3 associated with "somewhat more" as an example, but the others are unreported.)
Ledbetter et al. (2019)	Assess NEIs associated with advanced lighting technologies.	5-point scale	Scalar values derived from Lim, Wood, and Green (2009) and "within-sample" multipliers derived from the survey results. Both sets of scalar values were reported.

The Pacific Northwest National Laboratory (PNNL) analysis reported multipliers from the literature and in-sample multipliers (Ledbetter et al. 2019). The multipliers from the literature used in the PNNL study were extrapolated from the labeled hedonic scale constructed by Lim, Wood, and Green (2009).

The Lim, Wood, and Green study produced an LMS scale for the magnitude of liking/disliking sensations, called a labeled hedonic scale (LHS). The scale ranged from -100 to 100, with the extremes the most liked/disliked sensations imaginable, and intermediate labels of like/dislike "slightly", "moderately", "very much", and "extremely". The scale used by Lim, Wood, and Green, was not a valuation scale, and scale units were arbitrary. The PNNL study converted the numeric values of the LHS to percentage multipliers. Therefore, a value of zero/neutral on the LHS (equivalent to a response of "same value" in the PNNL study) is one. The value of 18 on the LHS (for "somewhat like") is converted to a multiplier of 1.18. This approach of converting the LHS scale into multipliers was not supported by other uses in the literature, but the values were similar to those derived from in-sample direct scaling in that study.

Table 4. Pacific Northwest National Laboratory LMS Multipliers

Relative Valuation	Multipliers from Literature	In-Sample Multipliers
Much More Value	1.55 or 1.44	1.56
Somewhat More Value	1.18	1.40
Same Value	1	0.88
Somewhat Less Value	0.82	0.52
Much Less Value	0.475 or 0.58	0.36

Table 5 displays the LMS values used for the residential market-rate program. The first set was based on the PNNL research and used an average of the PNNL values. The "more value" multiplier was an average of the "much more valuable" and "somewhat more valuable" multipliers used by PNNL. The "less value" multiplier was an average of the "much less valuable" and "somewhat less valuable" multipliers used by PNNL.

The second set of multipliers, the in-sample multipliers, was based on the survey responses shown above, collapsed across categories as described below.

- Winter Comfort: Combined Thermostat Only, Heating System, and HPwES. Water Heater Only was kept separate. This is based on different expected values and different actual values shown in the table above.
- Summer Comfort: All values were combined because of close mean values.
- Safety: Combined Water Heater Only and Heating System because these measures were expected to have the greatest impact on safety. Thermostat Only and HPwES were kept separate because of different values.
- Health: Combined all NEIs because there were few responses and the mean values were relatively close.
- Noise: Combined Thermostat and Water Heater Only because these were not expected to influence noise. Combined Heating System and HPwES because these may influence noise and the values were similar.

Table 5. LMS multipliers used for residential market-rate program

PNNL Applied Multipliers				Current Study In-Sample Multiplier								
PNNL Scale	PNNL Value	Current Study		Winter Comfort		Summer Comfort	Safety			Health	Noise	
		Scale	Value	Therm HVAC HPwES	DHW	All Meas	Therm	HVAC DHW	HPwES	All Meas	Therm DHW	HVAC HPwES
Much More	1.55	More Value	1.35	0.49	0.21	0.57	0.30	0.68	0.44	0.65	0.42	0.54
Somewhat More	1.18											
Same Value	1	Same Value	1	0.39	0.20	0.39	0.20	0.70	0.40	0.46	0.10	0.27
Somewhat Less	0.82	Less Value	0.65	0.37	N/A	0.05	N/A	0.30	0.15	1	0.05	0.22
Much Less	0.475											

NEI Estimates

We estimated NEI values for winter comfort, summer comfort, health, safety, and noise for both programs.

- For the market-rate program, these were calculated for thermostat only, water heater only, heating system, and HPwES participants.
- For the low-income program, these were calculated for baseload only, air sealing and insulation, and HVAC measure participants.

The estimates were derived using variations of the CV, DS, and LMS methods. We present a total of seven estimates for each NEI and measure combination for both the market-rate and low-income programs, as we included different bill savings estimates and different LMS multipliers.

Table 6 provides an example of the winter comfort valuation for the residential market-rate program. Additional information on all results is provided in the two fully detailed APPRISE NEI reports (2021).

Table 6. Annual winter comfort valuation for residential market-rate program

Participant Group	Weighted Mean NEI Value						
	Contingent Valuation	Direct Scaling		LMS – PNNL Multipliers		LMS – In-Sample Multipliers	
		Reported	Actual	Reported	Actual	Reported	Actual
Thermostat Only	$38	$9	$6	$23	$23	$9	$8
Water Heater Only	<$1	$0	$1	$1	$12	<$1	$2

Participant Group	Weighted Mean NEI Value						
	Contingent Valuation	Direct Scaling		LMS – PNNL Multipliers		LMS – In-Sample Multipliers	
		Reported	Actual	Reported	Actual	Reported	Actual
Heating System	$75	$89	$18	$207	$44	$76	$17
HPwES	$78	$120	$29	$273	$91	$100	$34
All	$64	$76	$16	$177	$45	$65	$17

Our recommended method is the LMS with participant reported bill savings and in-sample multipliers. This method utilizes participant responses for estimated bill savings, NEI values compared to bill savings, and a qualitative comparison of the value of the NEI to the bill savings. The participant's estimate of bill savings is preferred because the respondent is valuing the NEI relative to their perceived bill savings. The in-sample multiplier is preferred because it is derived from the participant's program experience. These multipliers are on the lower end of the methods and provide what we believe is a justifiable value for most of the NEIs.

Table 7 shows that the total mean annual value of the five estimated NEIs for the market-rate program was $19 for thermostat only participants, $21 for water heater only participants, $273 for heating system participants, and $332 for HPwES participants. The NEI with the highest value for heating system participants was the winter comfort improvement, with a value of $76. The NEI with the highest value for HPwES was the summer comfort improvement, with a value of $126.

Table 7. Market-Rate HPwES Program. Mean annual NEI values for selected NEI estimation method: LMS with reported bill savings and in-sample multipliers

Participant Group	Non-Energy Impact for Market-Rate Program					Total NEI
	Winter Comfort	Summer Comfort	Safety	Health	Noise	
Thermostat Only	$9	$5	$3	$1	$1	$19
Water Heater Only	<$1	$6	$8	<$1	$6	$21
Heating System	$76	$38	$62	$31	$66	$273
HPwES	$100	$126	$23	$44	$39	$332
All Programs	$65	$44	$43	$28	$49	$229

For low-income participants, Table 8 shows that the total mean annual value of the five estimated NEIs was $196 for baseload only participants, $228 for air sealing and insulation participants, and $386 for HVAC participants.

Table 8. Low-Income Energy Efficiency Program. Mean annual NEI values for selected NEI estimation method: LMS with reported bill savings and in-sample multipliers

Participant Group	Non-Energy Impact for Low-Income Energy Efficiency Program					Total NEI
	Winter Comfort	Summer Comfort	Safety	Health	Noise	
Electric Baseload	$72	$40	$34	$11	$39	$196
Air Sealing and Insulation	$72	$58	$36	$28	$34	$228
HVAC	$74	$88	$82	$97	$45	$386
All Participants	$72	$48	$41	$24	$39	$224

Limitations of this study's findings include the following.

- Survey response bias. While the surveys achieved response rates of 67 percent and 60 percent, there may be bias in the unmeasured characteristics of individuals who responded to the survey. Survey data were weighted to account for differences in observable factors.
- Respondent understanding and ability to answer questions. The surveys included questions that are difficult to comprehend and estimate a response for.
- Sample size. Once the samples are broken down by type of measure and respondents who answered specific questions, there are some small samples for the NEB analysis.

Recommendations

The study found that the different NEI estimation methods sometimes resulted in very different NEI values. The differences were based upon asking participants to report a dollar value for the NEI benefit compared to asking them to value it in relation to their bill savings.

Various levels of NEI impacts are expected based on the specific measures installed. For the market-rate participants, the estimated value ordering from this study generally matched expectations for relative valuations, though this was not the case for the low-income program participants. Market-rate participants who received heating system replacements and HPwES had the greatest NEI values for winter comfort, summer comfort, safety, health, and noise, consistent with higher bill savings and our expectations for higher NEIs.

The paper recommends specific values for the NEIs that vary based on the following.

- Program design, implementation, geography, and population served.
- Measures installed in the home.
- Efficacy of program delivery.

Based on the study, we make the following recommendations for future NEI research.

- Cognitive Interviewing: Conduct in-depth interviews with program participants to assess how they perceive questions, how they think about NEIs, and how researchers can best report their experiences.
- Compare Findings: Compare NEI values from this study to other studies that estimate NEI values based on surveys with current program participants.
- Direct Scaling Responses: Consider allowing responses greater than 100 percent for the value of the NEI relative to bill savings.
- LMS Categories: Include a greater number of categories instead of just more valuable than energy savings, the same value as energy savings, and less value than energy savings.

Additional research is needed with program participants to understand how best to value participant NEIs.

References

Amann, J. 2006. *Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole-House Retrofits Programs: A Literature Review*. Washington, DC: ACEEE. aceee.org/files/pdf/conferences/workshop/valuation/A061.pdf.

APPRISE. 2021. "Residential Energy Efficiency Program Non-Energy Impact Study." www.appriseinc.org/resource-library-selected-reports-non-energy-impact-research/.

APPRISE. 2021. "Low-Income Energy Efficiency Program Non-Energy Impact Study." www.appriseinc.org/resource-library-selected-reports-non-energy-impact-research/.

Clendenning, G., C. Browne, L. Hoefgen, R. Prahl, M. Cohen, and G. Azulay. 2012. "Measuring Participant Perspective Non-Energy Impacts (NEIs)." In *Proceedings of the 2012 ACEEE Summer Study on Energy Efficiency in Buildings* 2: 114-26. Washington, DC: ACEEE. aceee.org/files/proceedings/2012/data/papers/0193-000046.pdf.

Diamond, P., and J. Hausman. 1994. "Contingent Valuation: Is Some Number Better Than No Number?". *Journal of Economic Perspectives* 8 (4): 45-64.

Fuchs, L., L. Skumatz, and J. Ellefsen. 2004. "Non-Energy Benefits (NEBs) from ENERGY STAR: Comprehensive Analysis of Appliance, Outreach, and Homes Programs." In *Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings* 2:79-89. Washington, DC: ACEEE. s3.amazonaws.com/ilsag/SS04_Panel2_Paper08.pdf.

Green, B., G. Shaffer, and M. Gilmore. 1993. "Derivation and Evaluation of a Semantic Scale of Oral Sensation Magnitude with Apparent Ratio Properties." *Chemical Senses* 18 (6): 683-702.

Hausman, J. 2012. "Contingent Valuation: From Dubious to Hopeless." *Journal of Economic Perspectives* 26 (4): 43-56.

Horowitz, J. and K. McConnell. 2003. "Willingness to Accept, Willingness to Pay and the Income Effect." *Journal of Economic Behavior and Organization* 51 (4): 537-45.

Ledbetter, M., L. Skumatz, J. Penning, D. D'Souza, M. Santulli, V. Nubbe, and C. Elliott. 2019. *Energy Saving Opportunity from Advanced LED Lighting Research*. PNNL-29342. Richland, WA: Pacific Northwest National Laboratory. www.pnnl.gov/main/publications/external/technical_reports/PNNL-29342.pdf.

Lim, J., A. Wood, and B. Green. 2009. "Derivation and Evaluation of a Labeled Hedonic Scale." *Chemical Senses* 34: 739-51.

NMR Group. 2016. *Project R4 HES/HES-IE Process Evaluation and R31 Real-time Research.* Prepared for Connecticut Energy Efficiency Board, Eversource, and United Illuminating. energizect.com/sites/default/files/R4_HES-HESIE%20Process%20Evaluation,%20Final%20Report_4.13.16.pdf.

Pearson, D., and L. Skumatz. 2002. "Non-Energy Benefits Including Productivity, Liability, Tenant Satisfaction, and Others—What Participant Surveys Tell Us about Designing and Marketing Commercial Programs." In *Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings* 4:289-302. Washington, DC: ACEEE. aceee.org/files/proceedings/2002/data/papers/SS02_Panel4_Paper24.pdf.

Rosenbaum, D., E. Thompson, M. DeKraai, J. Laitner, J. Pursley. 2012. "The Energy, Economic and Environmental Impacts of Nebraska Energy Office's Dollar and Energy Savings Loan Program and Weatherization Assistance Program." University of Nebraska. neo.ne.gov/info/pubs/pdf/2012-wx-loan-final-report.pdf.

Skumatz, L. 2002. "Comparing Participant Valuation Results Using Three Advanced Survey Measurement Techniques: New Non-Energy Benefits (NEB) Computations of Participant Value." In *Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings* 8:307-20. Washington, DC: ACEEE. aceee.org/files/proceedings/2002/data/papers/SS02_Panel8_Paper25.pdf.

———. 2014. "Non-Energy Benefits/Non-Energy Impacts (NEBs/NEIs) and Their Role & Values in Cost-Effectiveness Tests: State of Maryland." Prepared for Natural Resources Defense Council, Inc. Superior, CO: SERA. sahlln.energyefficiencyforall.org/sites/default/files/2014_%20NEBs%20report%20for%20Maryland.pdf.

Skumatz, L., and J. Gardner. 2006. "Differences in the Valuation of Non-Energy Benefits According to Measurement Methodology: Causes and Consequences." In *Proceedings of the Association for Energy Service Professionals NESP Conference*. San Diego, CA: AESP. library.aesp.org/resources/Docuworks/file_display.cfm?id=421.