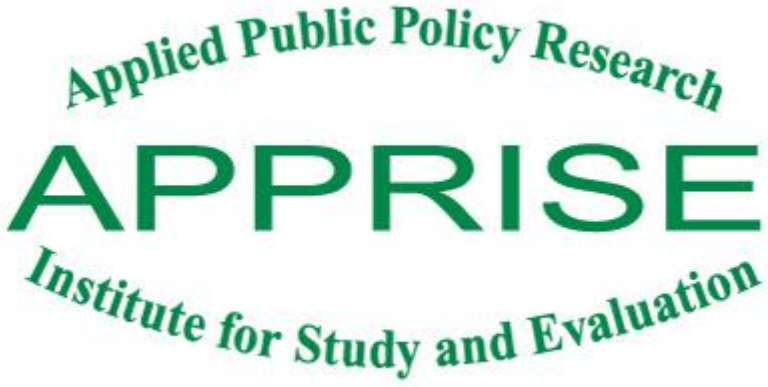

Residential Energy Efficiency Non-Energy Impacts

Final Report

October 2021

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Executive Summary

A Northeastern gas utility provides rebates, incentives, and financing to support home energy efficiency improvements. While the program helps 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 energy efficiency program participants. It does not assess societal NEIs such as economic, environmental, and infrastructure impacts, and it does not assess utility NEIs such as reductions in arrearage carrying costs and collections expenses.

Usage Impact Analysis

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 program on natural gas

consumption for 2019 participants. While some measures also impacted electric usage and costs, those data were not available for analysis.

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 this analysis are summarized below.

- Participants with only a thermostat installed and participants with only a water heater installed had statistically insignificant net savings values.
- Heating systems participants had mean annual net savings of 39 Therms, or 3.1 percent of pre-treatment usage.
- Home Performance with Energy Star (HPwES) participants had mean annual net savings of 202 Therms, or 16.8 percent of pre-treatment usage

Natural Gas Bill Analysis

Billing data were analyzed for the year prior to the audit and for the year after service delivery was completed. The key findings from this analysis 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.
- Participants in the heating system group reduced their annual bill amount by $9 on average, relative to the comparison group.
- After accounting for the comparison group, the bill reductions for thermostat only participants and water heater only participants were not statistically significant.

NEI Analysis

Non-Energy Impacts were estimated based on responses from a survey of program participants. Three different approaches were used to produce estimates.

- 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 participants. The survey questions addressed participants' perceived energy savings, NEI valuations, and relative valuations of the NEIs compared to energy savings.

The survey utilized a mixed mode phone/web approach. The cooperation rate, the completion rate for participants who were contacted and who were eligible for the survey, was 88 percent. The response rate was 67 percent.

The following specific sequence of questions was asked for each NEI to provide data for the NEI value calculations.

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

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.

NEI Estimates

The report estimated NEI values for winter comfort, summer comfort, health, safety, and noise for thermostat only, water heater only, heating system, and HPwES participants using variations of the CV, DS, and LMS methods. We present a total of seven estimates for each NEI and measure combination, as we included different bill savings estimates and different LMS multipliers.

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.

The total mean annual value of the five estimated NEIs 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.

Mean Annual NEI Values for Selected NEI Estimation Method
LMS with Reported Bill Savings and In-Sample Multipliers

Participant Group	Non-Energy Impact					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**

Findings & 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. The estimated value orderings from this study matched expectations for relative valuations in most cases. Participants who received heating system replacements and HPwES had the greatest NEI values for winter comfort, summer comfort, safety, health, and noise.

Based on these findings, 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.

I. Introduction

A Northeastern gas utility's residential energy efficiency program provides rebates, incentives, and financing to support home energy efficiency improvements. While the program helps 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 NEIs, and to recommend values for these benefits.

A. Research Goals

The goals of the NEI analysis were as follows.

- Apply several methodologies to measure the value of 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 NEI values using all available information.

B. Information Sources

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

- Program Data: We analyzed program data to develop a sample frame and select a stratified sample of 2019 participants for the NEI survey.

- Participant Survey: We conducted a mixed mode web/telephone survey with participants to collect information on perceptions of energy savings and the NEIs.

- Energy Usage: We analyzed energy usage to estimate the change in natural gas consumption that resulted from program participation.

- Energy Bills: We analyzed energy bills to estimate the change in natural gas costs that resulted from program participation.

The program is also expected to impact electric usage and costs in certain cases, but electricity is supplied by other utilities, and these data were not available for analysis.

C. NEI Estimation Literature

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.

Key weaknesses in the literature include the following.

- No information on how the benefits were calculated.
- Use of energy savings to calculate bill savings with no information on how the energy savings were calculated.
- Input sources that are not clearly documented.
- Input values from 20 or more years ago that are not valid for current conditions.
- Inclusion of benefits that were not found to be statistically significant.
- Exclusion of comparison groups even when specifically designed for the study.
- Estimated bill savings that ranged to unrealistic levels.
- Survey-estimated benefits that were based on sample sizes that could not provide statistically significant results.
- Use of surveys with very low response rates.
- Attribution factors based on "professional judgement".
- Double counting of benefits.
- No discounting of benefits when using a 15-year measure lifetime.

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 program participants. It does not assess societal NEIs such as economic, environmental, and infrastructural impacts, and it does not assess utility NEIs such as reductions in arrearage carrying costs and collections expenses

There are two methods that have typically been used to assess participant NEIs: direct estimation of NEIs through data on the specific impact, and surveys that ask the participants to value the impacts. An example of direct estimation is obtaining data on the reduction in medical costs that result from replacing the heating system in the home. While this approach has the potential to provide the most rigorous estimates, it fails to do so in practice because relevant data from the studied or similar program are not available, data from very different programs are used instead, sample sizes are very small, and results are often not statistically significant. Asking participants to value the health benefit is another method that has clear issues, as it is difficult or impossible for an individual to provide such valuation. However, given the challenges with the direct estimation approach, this study uses the participant survey valuation method to provide valuations for several key participant NEIs.

D. NEI Estimation Approach

The present report takes the survey-based approach to estimate participant NEIs. There are significant challenges with this type of research.

- Respondents sometimes provide a series of survey responses that are internally inconsistent. For example, a respondent may state that the improvement in noise level is

worth the same amount as their energy bill reduction yet report substantially different dollar values for the bill reduction and the valuation of the change in noise level.

- The value of some NEIs may be difficult for the respondent to accurately assess. For example, health and safety impacts may derive primarily from changes in risk for rare events (such as carbon monoxide poisoning), which are difficult both to evaluate and to value.
- Respondents often have difficulty assigning specific quantitative values to non-market goods.
- Respondents may attempt to please the interviewer or show appreciation for the program, leading to inflated NEI values. Alternatively, dissatisfied respondents may give "protest" responses (extreme negative values).
- Responses may be highly sensitive to the design of the survey; for example, the number of NEIs asked about, the order of questions, the wording of questions, and the timing of the survey (season/weekday/time of day).

Despite these limitations, this report attempts to use the survey method to provide the best possible estimate of NEI value for winter comfort, summer comfort, health, safety, and noise NEIs.

E. Organization of the Report

Four sections follow this introduction.

1) *Section II — Usage Impacts:* This section provides an analysis of the impacts of the program on natural gas usage by analyzing the pre- and post-treatment natural gas usage.

2) *Section III — Natural Gas Bill Analysis:* This section provides an analysis of the impacts of the program on natural gas costs by analyzing the pre- and post-treatment natural gas bills.

3) *Section IV — NEI Analysis:* This section discusses the survey methodology and provides estimates of the monetary value of NEIs achieved through the program.

4) *Section V — Findings and Recommendations*: This section provides a summary of key findings and recommendations with respect to NEIs.

Any errors or omissions in this report are the responsibility of APPRISE. Furthermore, the statements, findings, conclusions, and recommendations are solely those of analysts from APPRISE.

II. 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 program on natural gas consumption for 2019 participants. While some measures also impacted electric usage and costs, those data were not available for analysis. This section provides a description of the billing analysis methodology and a summary of the findings from that analysis.

A. Methodology

This section describes the evaluation data and methodology used in the usage impact analysis.

Evaluation Data

The utility provided APPRISE with 2019 participants' program data, usage data, and billing data from January 2018 through December 2020. Program participants who received services in 2019 were treated as the analysis group for this evaluation.

We analyzed natural gas usage for the year prior to the audit and the year following completion of service delivery. The analysis included as close to a full year of pre- and post-treatment data as possible. Usage data were weather normalized in the pre- and post-usage period to control for changes in weather.

Participants

Table II-1 provides information on the participants and data included in the usage analysis.

Table II-1
Treatment Group Definition

Group Description	Pre-Participation Dates	Post-Participation Dates
2019 Participants	1 year prior to audit date	1 year after project completion date

Participants were separated into groups based on the program and measures. This is important when estimating the usage, cost, and NEIs, which will all depend on the specific measures installed. The groups are illustrated in Table II-2.

- "HEA No Measures": Participants who received a Home Energy Assessment (HEA) but had no measures installed.
- "Thermostat Only": Participants who only had a Smart Thermostat installed.
- "Water Heater Only": Participants who only had a water heater installed.
- "Heating System": Participants with a new heating system or a new heating system and air conditioning system installed (but no air sealing and/or insulation).
- HPwES: Participants who had air sealing and/or insulation installed and may have also had a heating system or a heating system and an air conditioning system installed.

Table II-2
Measures Installed by Group

Participant Group	Measures Installed					
	Thermostat	Water Heater	Heating System	AC System	Air Sealing	Insulation
Thermostat Only	YES	NO	NO	NO	NO	NO
Water Heater Only	YES/NO	YES	NO	NO	NO	NO
Heating System	YES/NO	YES/NO	YES	YES/NO	NO	NO
HPwES	YES/NO	YES/NO	YES/NO	YES/NO	YES	

The usage analysis attempted to include as many 2019 participants as possible, but some were excluded due to missing data. Table II-3 provides the attrition analysis for participants in each group and participants in all programs. In addition to the groups listed above, there is a group of participants who only received the Home Energy Assessment (HEA) and had no installed measures. The table shows the percent of participants who were included in the usage impact analysis and those who completed the survey. Participants were eliminated if they did not have enough natural gas usage data or if they were extreme outliers.

The table refers to the two weather normalization models used to analyze the energy usage impacts – a proprietary "Degree Day" method that examines the relationship between natural gas usage and heating degree days, and the PRISM method.[1]

Overall, 70 percent of participants were included in the usage analysis and eight percent of those who received measures completed the survey (the overall survey response rate was 67 percent). Participants who only received the HEA and no measures were not included in the survey.

Table II-3
Usage Attrition Analysis

Inclusion Reason	HEA No Measures		Thermostat Only		Water Heater Only		Heating System		HPwES		All Programs	
	N	%	N	%	N	%	N	%	N	%	N	%
Participants	364	100%	339	100%	450	100%	2,587	100%	546	100%	**4,286**	**100%**
Had Any Usage Data	362	99%	339	100%	444	99%	2,574	99%	541	99%	**4,260**	**99%**
Enough Pre & Post Usage Data	325	89%	295	87%	388	86%	1,964	76%	415	76%	**3,387**	**79%**
Enough Pre & Post Usage Days	314	86%	288	85%	373	83%	1,734	67%	400	73%	**3,109**	**73%**
Degree Day Extremes Excluded	313	86%	283	83%	367	82%	1,689	65%	391	72%	**3,043**	**71%**
No Additional Degree Day Outliers	313	86%	280	83%	359	80%	1,686	65%	389	71%	**3,027**	**71%**
In Degree Day Analysis	313	86%	280	83%	359	80%	1,686	65%	389	71%	**3,027**	**71%**

[1]Fels, Margaret F. 1986. "PRISM: An Introduction." *Energy and Buildings*, 9 (1986): 5-18.

Inclusion Reason	HEA No Measures		Thermostat Only		Water Heater Only		Heating System		HPwES		All Programs	
	N	%	N	%	N	%	N	%	N	%	N	%
PRISM Extremes Excluded	312	86%	279	82%	357	79%	1,674	65%	387	71%	**3,009**	**70%**
No Additional PRISM Outliers	312	86%	279	82%	356	79%	1,674	65%	387	71%	**3,008**	**70%**
In PRISM Analysis	312	86%	279	82%	356	79%	1,674	65%	387	71%	**3,008**	**70%**
NEI Survey Respondent	0*	0%	83	24%	69	15%	67	3%	92	17%	**311**	**8%****

* HEA participants with no measures were excluded from the survey sample frame. They are included as a comparison group in the analysis.
** This percentage excludes participants that were in the HEA With No Measures group.

Table II-4 provides information on the composition of the participants and those with available data. While the distribution of those included in the usage analysis is very similar to the distribution of all participants across the programs, the survey respondents are less heavily weighted toward participants who installed a new heating system because the sample stratification was designed to include sufficient responses across all types of program participants.

Table II-4
Distribution of Program Participation

Participant Group	All Participants		Included in Usage Analysis		Responded to Survey	
	#	%	#	%	#	%
HEA With No Measures	364	8%	313	10%	0	0%
Thermostat Only	339	8%	280	9%	83	27%
Water Heater Only	450	10%	359	12%	69	22%
Heating System	2,587	60%	1,686	56%	67	22%
HPwES	546	13%	389	13%	92	30%
All Programs	**4,286**	**100%**	**3,027**	**100%**	**311**	**100%**

B. Natural Gas Impacts

This section provides the results from the natural gas usage analysis. It is important to note that there are likely to be significant changes in energy usage that are unrelated to the treatments for the 2019 participants. These changes are expected to result from stay-at-home orders put into place in March 2020 due to the onset of the COVID-19 Pandemic. Later results in this section attempt to control for those impacts.

Table II-5 displays the natural gas savings for all program participants and the subset of survey respondents. The table shows that mean energy savings estimated through the Degree Day model were 79 Therms or 6.4 percent of pre-treatment usage for all participants and 95 Therms or 8.4 percent of pre-treatment usage for the survey respondents, comprised of a different mix of participants. The full analysis group includes participants who only had the energy assessment and did not install any program measures, whereas the survey respondents group excludes participants with no measures installed. Estimated savings were lower when using

the PRISM model.[2] However, the net changes shown in the following tables have similar values for the Degree Day and PRISM models.

Table II-5
Annual Natural Gas Savings
All Participants

Normalization Method	Analysis Group					Survey Respondents				
	#	Total Savings (Therms)				#	Total Savings (Therms)			
		Usage		Annual Savings	% Saved		Usage		Annual Savings	% Saved
		Pre	Post				Pre	Post		
Raw Usage	3,027	1,195	1,049	147**	12.3%	311	1,102	945	156**	14.2%
Day Adjusted	3,027	1,305	1,140	165**	12.7%	311	1,204	1,029	175**	14.5%
Degree Day Normalized	3,027	1,235	1,156	79**	6.4%	311	1,137	1,042	95**	8.4%
Degree Day-PRISM Cases	3,008	1,233	1,152	81**	6.6%	311	1,137	1,042	95**	8.4%
PRISM Normalized	3,008	1,202	1,160	42**	3.5%	311	1,113	1,052	61**	5.5%

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

Table II-6 displays the heating degree day data that were used in the weather normalization process. The table shows that there was a reduction in heating degree days from the pre- to the post-treatment period, meaning that the winter preceding treatment was colder than the winter following treatment. The Raw- and Day-Adjusted Usage analysis that is not weather normalized shows higher savings than the weather-normalized approaches because it includes the reduction in usage that is due to a milder post-treatment winter in the energy savings estimate.

Table II-6
Average Heating Degree Days
Relative to 20-Year Average

Participant Group	Analysis Group					Survey Respondents				
	#	Pre-HDD	Post-HDD	HDD Difference		#	Pre-HDD	Post-HDD	HDD Difference	
				#	%				#	%
All Programs	3,027	4,557	4,168	-389**	-8.5%	311	4,546	4,176	-370**	-8.1%
HEA With No Measures	313	4,556	4,134	-422**	-9.3%	0	-	-	-	-
Thermostat Only	280	4,570	4,117	-453**	-9.9%	83	4,602	4,101	-501**	-10.9%
Water Heater Only	359	4,553	4,180	-372**	-8.2%	69	4,512	4,160	-353**	-7.8%
Heating System	1,686	4,558	4,172	-385**	-8.5%	67	4,542	4,197	-345**	-7.6%

[2] We found similar differences for other studies conducted during the COVID-19 pandemic. The difference is likely due to changes in usage patterns following the onset of pandemic restrictions in March 2020.

Participant Group	Analysis Group					Survey Respondents				
	#	Pre-HDD	Post-HDD	HDD Difference		#	Pre-HDD	Post-HDD	HDD Difference	
				#	%				#	%
HPwES	389	4,548	4,204	-344**	-7.6%	92	4,524	4,240	-284**	-6.3%
20-Year Average (2001-2020)	4,650									

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

Participants who received the HEA but did not have measures installed are expected to have little or no changes in their natural gas usage. An exception would be if participants received the audit and then installed energy efficiency measures outside of the program. However, such an occurrence is unlikely, as significant incentives are provided to program participants. Because these households participated in the program but did not install any measures, they provide a good counterfactual of the change in usage that would have occurred in the absence of the program installations.

Table II-7 displays the energy savings for the participants with no installed measures. The table shows that the Degree Day model estimated a reduction of 31 Therms, or 2.3 percent of pre-treatment usage. The PRISM normalization method found a small increase in usage that was not statistically significant.

Table II-7
Annual Natural Gas Savings
Home Energy Assessment Participants with No Measures

Normalization Method	Analysis Group				
	#	Total Savings (Therms)			
		Usage		Annual Savings	% Saved
		Pre	Post		
Raw Usage	313	1,295	1,182	113**	8.7%
Day Adjusted	313	1,415	1,290	125**	8.8%
Degree Day Normalized	313	1,349	1,318	31*	2.3%
Degree Day-PRISM Cases	312	1,342	1,317	25*	1.9%
PRISM Normalized	312	1,309	1,324	-15	-1.1%

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

Table II-8 displays the energy savings for HEA participants with a thermostat installed. The table shows that these participants saved 38 Therms or 3.2 percent of pre-treatment usage.

However, the comparison group that received no measures also had energy savings, so the net change was smaller and was not statistically significant.[3]

Table II-8
Annual Natural Gas Savings
Thermostat Only Participants

Normalization Method	Analysis Group					Comparison Group					Net Change	
	#	Total Savings (Therms)				#	Total Savings (Therms)					
		Usage		Annual Savings			Usage		Annual Savings			
		Pre	Post	Therms	%		Pre	Post	Therms	%	Therms	%
Raw Usage	280	1,162	1,040	122**	10.5%	313	1,295	1,182	113**	8.7%	9	0.8%
Day Adjusted	280	1,270	1,130	140**	11.0%	313	1,415	1,290	125**	8.8%	15	1.1%
Degree Day Normalized	280	1,195	1,157	38**	3.2%	313	1,349	1,318	31*	2.3%	7	0.6%
Degree Day-PRISM Cases	279	1,196	1,157	39**	3.3%	312	1,342	1,317	25*	1.9%	14	1.2%
PRISM Normalized	279	1,167	1,174	-6	-0.5%	312	1,309	1,324	-15	-1.1%	8	0.7%

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

Table II-9 displays the energy savings for participants who only installed a water heater. The table shows that these participants saved 21 Therms, or two percent of pre-treatment usage. However, the net change was not statistically significant.

Table II-9
Annual Natural Gas Savings
Water Heater Only Participants

Normalization Method	Analysis Group					Comparison Group					Net Change	
	#	Total Savings (Therms)				#	Total Savings (Therms)					
		Usage		Annual Savings			Usage		Annual Savings			
		Pre	Post	Therms	%		Pre	Post	Therms	%	Therms	%
Raw Usage	359	1,053	967	86**	8.2%	313	1,295	1,182	113**	8.7%	-27*	-2.6%
Day Adjusted	359	1,151	1,050	102**	8.8%	313	1,415	1,290	125**	8.8%	-24#	-2.1%
Degree Day Normalized	359	1,085	1,064	21**	2.0%	313	1,349	1,318	31*	2.3%	-10	-0.9%
Degree Day-PRISM Cases	356	1,088	1,064	23**	2.2%	312	1,342	1,317	25*	1.9%	-2	-0.1%
PRISM Normalized	356	1,064	1,080	-16**	-1.5%	312	1,309	1,324	-15	-1.1%	-1	-0.1%

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

[3] Other research that APPRISE conducted during the COVID-19 period also showed a reduction in natural gas usage for comparison groups. While the opposite was expected, we hypothesize that gas usage declined because of an increase in electric waste heat that resulted from increased use of devices and appliances, and due to less than expected heat setback while out of the home in the pre-COVID period.

Table II-10 displays the energy savings for participants who had heating system replacements. These participants saved 71 Therms, or 5.6 percent of their pre-period usage. The net savings was 39 Therms or 3.1 percent of pre-treatment usage.

Table II-10
Annual Natural Gas Savings
Heating System Participants

Normalization Method	Analysis Group					Comparison Group					Net Change	
	#	Total Savings (Therms)				#	Total Savings (Therms)					
		Usage		Annual Savings			Usage		Annual Savings			
		Pre	Post	Therms	%		Pre	Post	Therms	%	Therms	%
Raw Usage	1,686	1,221	1,080	141**	11.6%	313	1,295	1,182	113**	12.2%	28*	2.3%
Day Adjusted	1,686	1,332	1,173	159**	11.9%	313	1,415	1,290	125**	12.6%	34**	2.5%
Degree Day Normalized	1,686	1,261	1,190	71**	5.6%	313	1,349	1,318	31*	7.3%	39**	3.1%
Degree Day-PRISM Cases	1,674	1,259	1,184	75**	5.9%	312	1,342	1,317	25*	7.3%	50**	4.0%
PRISM Normalized	1,674	1,226	1,190	36**	2.9%	312	1,309	1,324	-15	4.6%	51**	4.1%

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

Table II-11 displays the energy savings for participants who installed air sealing and/or insulation. These participants may also have installed a heating system. The table shows that the mean savings were 233 Therms, or 19.5 percent of pre-treatment usage. The net savings were 202 Therms or 16.8 percent of pre-treatment usage.

Table II-11
Annual Natural Gas Savings
HPwES Participants

Normalization Method	Analysis Group					Comparison Group					Net Change	
	#	Total Savings (Therms)				#	Total Savings (Therms)					
		Usage		Annual Savings			Usage		Annual Savings			
		Pre	Post	Therms	%		Pre	Post	Therms	%	Therms	%
Raw Usage	389	1,158	885	273**	23.6%	313	1,295	1,182	113**	12.2%	160**	13.8%
Day Adjusted	389	1,266	964	302**	23.8%	313	1,415	1,290	125**	12.6%	177**	13.9%
Degree Day Normalized	389	1,197	964	233**	19.5%	313	1,349	1,318	31*	7.3%	202**	16.8%
Degree Day-PRISM Cases	387	1,194	959	234**	19.6%	312	1,342	1,317	25*	7.3%	209**	17.5%
PRISM Normalized	387	1,164	963	201**	17.3%	312	1,309	1,324	-15	4.6%	216**	18.5%

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

Table II-12 displays the Degree Day normalized usage values for participants in each program, using the HEA participants with no measures as the comparison group. After accounting for the comparison group, the savings for participants with thermostat only and water heater only

were not statistically significant. However, participants who installed heating systems had net savings of 39 Therms, or 3.1 percent of their pre-period usage, and participants who installed air sealing and/or insulation had net savings of 202 Therms, or 16.8 percent of their pre-period usage.

Table II-12
Annual Natural Gas Savings
By Measure Installation

Participant Group	Treatment Group					Comparison Group					Net Change	
	#	Total Savings (Therms)				#	Total Savings (Therms)					
		Usage		Annual Savings			Usage		Annual Savings			
		Pre	Post	Therms	%		Pre	Post	Therms	%	Therms	%
Thermostat Only	280	1,195	1,157	38**	3.2%	313	1,349	1,318	31*	2.3%	7	0.6%
Water Heater Only	359	1,085	1,064	21**	2.0%						-10	-0.9%
Heating System	1,686	1,261	1,190	71**	5.6%						39**	3.1%
HPwES	389	1,197	964	233**	19.5%						202**	16.8%
Total	**2,714**	**1,222**	**1,138**	**84****	**6.9%**						**53****	**4.3%**

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

C. Summary

We conducted an analysis of the impact of program services on participants' annual natural gas usage. The key findings from this analysis are summarized below.

- Participants who installed measures had average gross annual savings of 84 Therms or 6.9 percent of pre-treatment usage.
- The comparison group, participants who installed no measures, had average savings of 31 Therms or 2.3 percent of pre-treatment usage.
- Participants with only a thermostat installed and participants with only a water heater installed had statistically insignificant net savings values.
- Heating system participants had net savings of 39 Therms, or 3.1 percent of pre-treatment usage.
- HPwES participants had net savings of 202 Therms, or 16.8 percent of pre-treatment usage.

III. Natural Gas Bill Analysis

This section provides a description of the research methodology and findings from an analysis of the billing statistics for program participants.

A. Methodology

This section describes the evaluation data and methodology for the billing impact analysis.

Billing data were analyzed for the year prior to the audit and for the year after service delivery was completed. 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 period to include the participants in the analysis.

Table III-1 displays the billing attrition analysis. Of the participants for which we received any data, 69 percent survived the attrition process for the billing analysis. The group with the highest percentage surviving attrition was the HEA participants with no measures installed, with 84 percent of those participants included in the billing analysis. The group with the lowest percentage surviving attrition was the heating system participants, with 64 percent of those participants included.

Table III-1
Billing Attrition Analysis

Exclusion Reason	HEA With No Measures		Thermostat Only		Water Heater Only		Heating System		HPwES		All Programs	
	N	%	N	%	N	%	N	%	N	%	N	%
Participants	364	100%	339	100%	450	100%	2,587	100%	546	100%	4,286	100%
Fewer Than 11 Months of Usage Charges in Pre/Post Period	305	84%	281	83%	364	81%	1,682	65%	383	70%	3,015	70%
Outliers Removed	305	84%	277	82%	350	78%	1,651	64%	374	68%	2,957	69%
Analysis Group	305	84%	277	82%	350	78%	1,651	64%	374	68%	2,957	69%
Survey Respondents	0*	0%	79	23%	67	15%	65	3%	89	16%	300	8%**

* We excluded HEA participants with no measures from the survey sample frame.
** This percentage excludes participants that were in the HEA With No Measures group.

B. Billing Analysis

This section provides findings on the impacts of on natural gas bills.

Table III-2 displays the average natural gas bills in the pre- and post-analysis periods for participants and for those who responded to the survey. The bill reductions for participants were similar to the reductions for the survey respondents. Participants' charges declined by $50 on average, or 10.7 percent of pre-period charges. Survey respondents' charges declined by $58, or 13.4 percent of pre-period charges. Among the groups, the HPwES participants,

with the most intensive energy treatments and the greatest energy savings, experienced the most substantial decline in natural gas bills, with a reduction equivalent to 22.8 percent of their pre-period charges.

Table III-2
Annual Natural Gas Bill Savings
All Participants and Survey Respondents

Participant Group	Analysis Group					Survey Respondents				
	#	Gas Charges		Change	% Change	#	Gas Charges		Change	% Change
		Pre	Post				Pre	Post		
All Programs	2,957	$467	$418	-$50**	-10.7%	300	$436	$377	-$58**	-13.4%
HEA With No Measures	305	$498	$462	-$37**	-7.4%	0	-	-	-	-
Thermostat Only	277	$453	$415	-$38**	-8.4%	79	$449	$409	-$41**	-9.0%
Water Heater Only	350	$416	$387	-$29**	-7.0%	67	$418	$390	-$27**	-6.5%
Heating System	1,651	$477	$431	-$46**	-9.7%	65	$450	$394	-$56**	-12.5%
HPwES	374	$458	$354	-$104**	-22.8%	89	$427	$328	-$99**	-23.3%

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

Table III-3 displays the savings for participants, using HEA participants with no measures as the comparison group. The use of a comparison group in the billing analysis is even more important than in the usage analysis, as these cost savings are not weather-normalized.

Participants with a heating system installed had mean net savings of $9, which is equivalent to two percent of their pre-treatment gas charges, and participants who participated in HPwES had mean net savings of $68, or 15 percent of pre-treatment natural gas charges.

Table III-3
Annual Natural Gas Bill Savings
By Measures Installed

Participant Group	Treatment Group					Comparison Group					Net Change	
	#	Gas Charges		Change	% Change	#	Gas Charges		Change	% Change	$	%
		Pre	Post				Pre	Post				
Thermostat Only	277	$453	$415	-$38**	-8.4%	305	$498	$462	-$37**	-7.4%	-$1	-0.3%
Water Heater Only	350	$416	$387	-$29**	-7.0%						$8	1.9%
Heating System	1,651	$477	$431	-$46**	-9.7%						-$9#	-2.0%

Participant Group	Treatment Group					Comparison Group					Net Change	
	#	Gas Charges		Change	% Change	#	Gas Charges		Change	% Change		
		Pre	Post				Pre	Post			$	%
HPwES	374	$458	$354	-$104**	-22.8%						-$68**	-14.8%
Total	**2,652**	**$464**	**$412**	**-$51****	**-11.1%**						**-$15****	**-3.1%**

**Denotes significance at the 99 percent level. *Denotes significance at the 95 percent level. #Denotes significance at the 90 percent level.

Table III-4 displays the detailed distribution of gross natural gas savings for the participants (including those who only received a home energy assessment). HPwES participants had median annual gross savings of $98, and ten percent of these participants had gross annual savings of more than $211.

Table III-4
Annual Natural Gas Bill Savings Distribution

Participant Group	Observations	Energy Savings ($)					
		Mean	Percentile				
			P10	P25	P50	P75	P90
All Programs	2,957	$50	-$32	$12	$45	$88	$145
HEA With No Measures	305	$37	-$38	-$1	$33	$70	$119
Thermostat Only	277	$38	-$27	$10	$42	$73	$106
Water Heater Only	350	$29	-$27	$5	$31	$53	$86
Heating System	1,651	$46	-$40	$10	$43	$85	$138
HPwES	374	$104	$13	$55	$98	$152	$211

Note: A reduction in the customer's bill from the pre to the post period is considered a positive savings value for this table.

C. Summary

We conducted an analysis of the impact of program services on participants' natural gas charges. The key findings from this analysis are summarized below.

- The treatment group, participants who received measures through the program, reduced their annual natural gas bill by $51 on average, or 11.1 percent of their pre-treatment bill amount.
- Relative to the comparison group, participants with installed measures reduced their annual bill by $15 on average.
- 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.
- Participants in the heating system group reduced their annual bill amount by $9 on average, relative to the comparison group.
- After accounting for the comparison group, the bill reductions for thermostat only participants and water heater only participants were not statistically significant.

IV. NEI Analysis

This section discusses the NEI survey conducted as part of this study, several approaches for valuing Non-Energy Impacts (NEIs) from the program, and the estimates derived from these approaches.

A. Survey Methodology

APPRISE conducted surveys with 393 2019 participants. The survey questions addressed participants' perceived energy savings, NEI valuations, and relative valuations of the NEIs compared to natural gas savings. The ten-minute web/telephone surveys were conducted between February 22, 2021 and March 28, 2021.

The survey utilized a mixed mode phone/web approach. We mailed advance letters with a $5 cash incentive to all potential respondents. These letters included a toll-free number and the website for the online survey. We also sent a series of three emails to the selected sample.

A sample of 700 participants was selected from the 3,953 participants with data. A valid telephone number was required to be included in the sample. Participants were separated into the same groups as those used in the usage and billing analysis, with additional detail by more specific types of measures or incentives. Table IV-1 presents the number of participants by group in the sample frame, selected sample, and completed surveys.

Table IV-1
Distribution of Sample Frame, Selected Sample, and Completed Surveys

Participant Group	Sample Frame	Selected Sample	Completed Surveys
Thermostat Only	339	150	97
Water Heater Only	450	100	79
Heating System			
On-Bill Repayment – Heating System	351	15	7
Rebate – Heating System	1,940	85	39
On-Bill Repayment – Heating System & Air Conditioning	308	100	55
HPwES			
Heating, AC, & Insulation and/or Air Sealing	322	81	49
Heating & Insulation and/or Air Sealing	77	19	12
Insulation and/or Air Sealing Only	166	100	55
Total	**3,953**	**700**	**393**

Table IV-2 furnishes information on the survey response. While all sample participants had a telephone number, 671 of the 700 participants had an email address. Fifty-nine percent of the surveys were completed online and 41 percent were conducted via telephone.

The most common non-interview reasons were that there was no response from the participant, or the respondent could not confirm participation. The cooperation rate, the completion rate for participants who were contacted and who were eligible for the survey, was 88 percent. The response rate was 67 percent.

Table IV-2
Survey Response
By Contact Information Available

Survey Response Status	Contact Information Available			
	Phone Number		Email	
	#	%	#	%
Total Selected	**700**	**100%**	**671**	**100%**
Voicemail / No Answer	160	23%	154	23%
Not Eligible	61	9%	57	8%
Refusal	37	5%	35	5%
Wrong/Non-Working Number	27	4%	26	4%
Partial Complete	16	2%	15	2%
Callback Requested	5	1%	4	1%
Deceased	1	0%	0	0%
Complete	**393**	**56%**	**380**	**57%**
Cooperation Rate	-	**88%**	-	**88%**
Response Rate	-	**67%**	-	**67%**

Because the distribution of participants who completed the survey differed from the sample frame, we developed weights to represent the participants.

Generally, weights are used at the survey respondent level. However, 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 valuation method and the NEI. For example, the mean summer comfort valuation using the CV method used a different set of weights than the mean winter comfort valuation using the CV method.

For the sake of comparison, we also computed the weighted means using a simpler weighting scheme with the same set of weights for all survey questions. Those figures are not reported in the tables below, but the overall means were similar between the two weighting schemes.

B. Non-Energy Impact Valuation Methodologies

Surveys are often used to value the participant NEIs that are difficult to measure directly. While participant response may be the best possible method to value the NEIs, it has inherent limitations due to the difficulty of precisely valuing these benefits.[4]

We used three different methods to value the NEIs.

- Contingent Valuation: We asked respondents to estimate the dollar value of each benefit.
- Direct Scaling: We asked respondents to value each benefit as a percent of the energy savings they experienced from the program.
- Labeled Magnitude Scaling: We asked respondents to value each benefit as more or less valuable than the energy savings from the program.

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.[5] 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.[6] The CV method also suffers from known inconsistencies wherein valuations differ significantly based on the context and the specific questions asked.[7] 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.[8]

[4] Pigg, Scott, Maddie Koolbeck, Leith Nye, Shannon Stendel, Melanie Lord, and Hayley McLeod. 2021. "Addressing Non-Energy Impacts of Weatherization", ORNL/SPR-2020/1840, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[5] Skumatz, Lisa. 2014. "Non-Energy Benefits/Non-Energy Impacts (NEIs/NEIs) and Their Role & Values in Cost-Effectiveness Tests: State of Maryland", prepared for Natural Resources Defense Council (NRDC), Superior, CO.

[6] Horowitz, J. and K. McConnell. 2003. "Willingness to Accept, Willingness to Pay and the Income Effect." *Journal of Economic Behavior and Organization* 51: 537-545.

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

[8] Diamond, P. A., & Hausman, J. A. (1994). Contingent valuation: is some number better than no number?. *Journal of economic perspectives*, *8*(4), 45-64.

The top values for the 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.[9] Values that were excluded from the 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. After excluding values above the 98th percentile for each NEI, 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 the impacts. Asking respondents to put a dollar value on NEIs may seem too hypothetical or arbitrary, and respondents may not consider the true value of the impact.[10] On average across all five NEI categories, only 22 percent of survey respondents said they experienced a change and provided a dollar value for that change. Many respondents, ranging from 40 to 77 percent for the NEIs studied, said they experienced no change in the NEI, 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, as compared to other valuation methods and other studies.[11] 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.[12]

However, participants are sometimes confused by the questions used in the DS method. For example, the survey asked, "How 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,[13] 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.

[9] Skumatz, Lisa. 2002. "Comparing Participant Valuation Results Using Three Advanced Survey Measurement Techniques: New Non-Energy Benefits (NEI) Computations of Participant Value." Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar, Washington, DC.

[10] Skumatz, Lisa and John Gardner. 2006. "Differences in the Valuation of Non-Energy Benefits According to Measurement Methodology: Causes and Consequences." Proceedings of the Association for Energy Service Professionals NESP Conference San Diego, CA, AESP, Clearwater FL.

[11] Clendenning, G., C. Browne, L. Hoefgen, R. Prahl, M. Cohen, and G. Azulay. 2012. "Measuring Perspective Non-Energy Impacts (NEIs)." ACEEE Summer Study.

[12] Barkett, Brent, Nicole Wobus, Scott Dimetrosky, Rachel Freeman, and Daniel Violette. 2006. "Non-Energy Impacts Evaluation." New York State Energy Research and Development Authority.

[13] Fuchs, Leah, Lisa Skumatz, and Jennifer Ellefsen. 2004. "Non-Energy Benefits (NEIs) from ENERGY STAR: Comprehensive Analysis of Appliance, Outreach, and Homes Programs." In Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings. Washington, D.C.: American Council for an Energy-Efficient Economy.

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.

- "What would you estimate the change in your annual natural gas bill was compared to the year before you received the program services?" [14]

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, as shown in Section III of this report. We applied the gross change in bills, because this is the actual change in energy costs that the respondent experienced (although the net change is a better estimate of the actual impact of the program). From the survey data, 46 percent of respondents reported a dollar value for the change in their annual utility bill (including those who said it did not change and who were assigned a value of $0). On the other hand, 76 percent of survey respondents had an estimate from the billing analysis (the others did not have sufficient data to be included in the analysis).

Table IV-3 compares the distribution of reported and actual bill savings by participant group. 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 percent of HPwES participants who reported bill savings estimated annual savings values greater than $600.

Table IV-3
Distribution of Reported and Actual Bill Savings
By Participant Group

Participant Group	Bill Savings	#	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

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

Participant Group	Bill Savings	#	Distribution of Values					
			Mean	Min	P25	Median	P75	Max
Overall	Reported	180	$195	-$456	$0	$10	$240	$1,700
	Actual	300	$58	-$233	$14	$51	$92	$499

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.[15]

LMS was adapted to 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.[16]

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 were 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.[17]

[15] Green, B. G., Shaffer, G. S., & Gilmore, M. M. (1993). Derivation and evaluation of a semantic scale of oral sensation magnitude with apparent ratio properties. *Chemical senses*, *18*(6), 683-702; Cardello, A. V., Schutz, H. G., Lesher, L. L., & Merrill, E. (2005). Development and testing of a labeled magnitude scale of perceived satiety. *Appetite*, *44*(1), 1-13; Lim, J. (2011). Hedonic scaling: A review of methods and theory. *Food quality and preference*, *22*(8), 733-747.

[16] Pearson, D., & Skumatz, (2002) L. A. 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 Summer Study on Energy Efficiency in Buildings* (p. 2); Ledbetter, M. R., Skumatz, L. A., Penning, J. P., D'Souza, D. C., Santulli, M. E., Nubbe, V. A., & Elliott, C. T. (2019). *Energy Saving Opportunity from Advanced LED Lighting Research* (No. PNNL-29342). Pacific Northwest National Lab.(PNNL), Richland, WA (United States); NMR Group, (2016). *Project R4 HES/HES-IE Process Evaluation and R31 Real-time Research;*
https://energizect.com/sites/default/files/R4_HES-HESIE%20Process%20Evaluation,%20Final%20Report_4.13.16.pdf

[17] Amann, Jennifer. 2006. "Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole-House Retrofits Programs: Literature Review." Report Number A061. American Council for an Energy-Efficient Economy.

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, all but one of the reviewed studies did not report the multiplier values used and instead stated that the qualitative value responses were translated to dollar values "[u]sing previous research."[18]

Table IV-4 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 IV-4
Labeled Magnitude Scaling Literature Review

Study	Objective	Scale	Source of Scalar Values
Skumatz (2002)[19]	Assess NEIs associated with a residential weatherization assistance program in CT	5-point scale	Unreported survey results
Fuchs, Skumatz, and Ellefsen (2004)[20]	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)[21]	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)[22]	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)[23]	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.

[18] DeKraii, Laitner, Pursley, Rosenbaum and Thompson. 2012. "The Energy, Economic and Environmental Impacts of Nebraska's Energy Office's Dollar and Energy Savings Loan Program and Weatherization Assistance Program." University of Nebraska.
[19] Skumatz, 2002, *op. cit.*
[20] Fuchs, Skumatz, and Ellefsen, 2004, *op. cit.*
[21] Lim, J., Alison Wood, and Barry G. Green, 2009. "Derivation and Evaluation of a Labeled Hedonic Scale", *Chemical Senses* 34 2009, November.
[22] NMR Group, (2016). *Project R4 HES/HES-IE Process Evaluation and R31 Real-time Research;* https://energizect.com/sites/default/files/R4_HES-HESIE%20Process%20Evaluation,%20Final%20Report_4.13.16.pdf
[23] Ledbetter M.R., L.A. Skumatz, J.P. Penning, D.C. D'Souza, M.E. Santulli, V.A. Nubbe, and C.T. Elliott. 2019. "Energy Saving Opportunity from Advanced LED Lighting Research." PNNL-29342. Richland, WA: Pacific Northwest National Laboratory.

The Pacific Northwest National Laboratory (PNNL) analysis conducted by Ledbetter et al (2019) reported multipliers from the literature and in-sample multipliers.[24] 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 IV-5
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 IV-6 displays the multipliers derived from the participant survey. The mean values displayed are the average percentage values provided for an NEI by a given subset of survey respondents. In general, the means for more value were greater than those for the same value, which were greater than those for less value. However, sample sizes within NEI, measure group, and LMS group were small, and there were a few exceptions.

Table IV-6
LMS In-Sample Multipliers

Non-Energy Impact	Labelled Magnitude Scale	Participant Group							
		Thermostat Only		Water Heater Only		Heating System		HPwES	
		Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Winter Comfort	More Value	22	.40	8	.21	40	.54	53	.49
	Same Value	10	.43	4	.20	9	.38	5	.32

[24] *Ibid.*

Non-Energy Impact	Labelled Magnitude Scale	Participant Group							
		Thermostat Only		Water Heater Only		Heating System		HPwES	
		Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
	Less Value	1	0	0	-	1	0	4	.55
Summer Comfort	More Value	14	.51	6	.58	41	.54	45	.61
	Same Value	6	.33	1	.50	4	.50	12	.38
	Less Value	0	-	0	-	2	.05	0	-
Safety	More Value	7	.30	13	.57	23	.73	20	.44
	Same Value	2	.20	1	.80	2	.65	1	.40
	Less Value	0	-	0	-	2	.30	2	.15
Health	More Value	5	.54	7	.61	15	.71	13	.65
	Same Value	1	.30	0	-	0	-	4	.50
	Less Value	0	-	0	-	0	-	1	1
Noise	More Value	5	.34	14	.45	35	.58	14	.45
	Same Value	2	.20	9	.08	8	.38	7	.14
	Less Value	0	-	4	.05	6	.23	5	.20

Table IV-7 displays the LMS values used in this study. 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, were 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 IV-7
LMS Multipliers

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											

Survey Data Analysis

The following adjustments were made to the raw survey responses.

- If a respondent said their energy bills had declined since the program services, we considered their reported savings to be positive regardless of the sign they used.
  - For example, someone who said their bill was lower and said the change in their bill was +$40 was treated as having reported savings of $40.
- Respondents who said their energy bill was the same as it had been prior to program services were assigned a value of $0 for their reported bill savings. The exception to this is participants who said their bill was the same, but then reported nonzero savings. These participants retained their reported bill savings value.
- Four reported natural gas savings values were extreme outliers that we excluded from the analysis. These values were excluded from any calculation that used reported savings.[25] The reported savings values for these participants were -$900, -$540, $2500, and $6600.
- If the respondent's reported savings were negative, then their valuation using either of the methods that utilized reported savings was set to $0.
- If the respondent's actual savings were negative, then their valuation using either of the methods that utilized actual savings was set to $0.
- Respondents who said they experienced no change in an NEI area were assigned a valuation of $0 for that NEI for each of the valuation methods.

[25] However, the participants were included if they reported no change in the NEI and therefore had a zero valuation.

C. NEI Valuation

This section provides findings from the NEI analysis using the NEI valuation approaches discussed above. We focused on five key participant NEIs to keep the survey to a relatively short length and obtain good response rates. The following NEIs were addressed.

- Winter Comfort
- Summer Comfort
- Safety
- Health
- Noise

Winter Comfort

The sequence of survey questions used to estimate participants' valuation of the change in winter comfort was as follows. (The same sequence was used for the other NEIs.)

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

Table IV-8A displays the percent of respondents who had the data needed to compute each type of valuation. The contingent valuation (CV) method was the only method that allowed negative valuations. The CV method also had the highest percentage of participants with missing values, 49 percent of all respondents, due to the challenge of providing a dollar value. The Labeled Magnitude Scale (LMS) using actual bill changes had values from 79 percent of respondents. For each valuation method, participants with valuations of zero constituted a majority of the participants with non-missing values.

Table IV-8A
Status of NEI Value by Method
Winter Comfort

NEI Value	Valuation Method									
	Contingent Valuation		Direct Scaling				Labeled Magnitude Scaling			
			Reported		Actual		Reported		Actual	
	#	%	#	%	#	%	#	%	#	%
Included Values										
• Positive	36	9%	46	12%	90	23%	52	13%	134	34%
• Negative	6	2%	0	0%	0	0%	0	0%	0	0%
• Zero	159	40%	186	47%	188	48%	193	49%	177	45%
All Included Values	201	51%	232	59%	278	71%	245	62%	311	79%
Missing	192	49%	161	41%	115	29%	148	38%	82	21%
Total	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**

Table IV-8B displays the number of respondents with sufficient information for each of the valuation methods for each participant group. The LMS method using actual savings values yielded the largest sample size, with 311 respondents. Methods using actual savings yielded larger sample sizes than those using reported savings because respondents were less likely to estimate natural gas savings than they were to have the data necessary to calculate an actual estimate of that savings.

Table IV-8B
Number of Respondents per Valuation Method
Winter Comfort

Participant Group	Number of Respondents				
	Contingent Valuation	Direct Scaling		Labeled Magnitude Scaling	
		Reported	Actual	Reported	Actual
Thermostat Only	55	65	71	68	76
Water Heater Only	57	59	68	62	72
Heating System	42	53	59	57	70
HPwES	47	55	80	58	93
All	**201**	**232**	**278**	**245**	**311**

Table IV-8C displays the weighted mean winter comfort valuations. As expected, the water heater only participants had very low valuations of their change in winter comfort, with values ranging from $0 to $12. The HPwES participants had mean valuations ranging from $29 to $273. The DS method using actual bill changes had the lowest winter comfort valuation for

HPwES participants and the LMS using PNNL multipliers and reported bill changes had the highest valuation. The values for the LMS method using multipliers derived from the sample were similar to the DS method.

Table IV-8C
Annual Winter Comfort Valuation

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
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**

Table IV-8D displays the distribution of each winter comfort valuation to provide a more detailed comparison of the results from the various measurement approaches.

- Thermostat Only: The CV is the only approach that allows for a negative value. The minimum valuation for the thermostat only participants was -$350. This group also had higher positive values using the CV method than using the other methods. While the 90th percentile using the CV method was $100, the next closest value was $85 using the LMS with the PNNL multipliers and actual bills, and the lowest was $3 using the DS with reported bills.

- Water Heater Only: No respondents provided a negative value for winter comfort for the water heater only participants. As expected, most winter comfort values were zero, as the water heater was not expected to impact winter comfort. However, using the LMS with the PNNL multipliers and actual bills, ten percent had a value greater than $91.

- Heating System: The LMS with PNNL multipliers and reported bills yielded the highest valuation for these participants. While 25 percent had a value over $135 using the LMS – Reported PNNL multiplier approach, 25 percent had a value over $85 using the LMS with PNNL multipliers and actual bills. The lowest value was using the DS method with actual bills, where 25 percent had a valuation over only $5. Differences were much larger in the upper tail of the distribution.

- HPwES: The lowest valuation for the HPwES participants was -$3,000. While ten percent had a valuation over $608 using the LMS-Reported Bill PNNL multiplier approach, ten percent had a valuation over $300 using the CV approach, and ten percent had a valuation over only $49 with the DS-Actual approach.

Table IV-8D
Distribution of Annual Winter Comfort Valuations
By Measures and Valuation Method

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
Thermostat Only									
Contingent Valuation	55	$38	-$350	$0	$0	$0	$100	$500	$600
Direct Scaling - Reported	65	$9	$0	$0	$0	$0	$3	$40	$300
Direct Scaling - Actual	71	$6	$0	$0	$0	$0	$20	$37	$78
LMS – Reported (PNNL)	68	$23	$0	$0	$0	$0	$20	$270	$405
LMS – Actual (PNNL)	76	$23	$0	$0	$0	$36	$85	$108	$183
LMS – Reported (In-Sample)	68	$9	$0	$0	$0	$0	$8	$99	$148
LMS – Actual (In-Sample)	76	$8	$0	$0	$0	$13	$31	$41	$71
Water Heater Only									
Contingent Valuation	57	$0	$0	$0	$0	$0	$0	$0	$3
Direct Scaling - Reported	59	$0	$0	$0	$0	$0	$0	$0	$0
Direct Scaling - Actual	68	$1	$0	$0	$0	$0	$3	$9	$22
LMS – Reported (PNNL)	62	$1	$0	$0	$0	$0	$0	$0	$68
LMS – Actual (PNNL)	72	$11	$0	$0	$0	$0	$43	$91	$144
LMS – Reported (In-Sample)	62	$0	$0	$0	$0	$0	$0	$0	$11
LMS – Actual (In-Sample)	72	$2	$0	$0	$0	$0	$8	$14	$29
Heating System									
Contingent Valuation	42	$75	-$10	$0	$0	$25	$400	$500	$600
Direct Scaling - Reported	53	$89	$0	$0	$0	$50	$125	$300	$1,700
Direct Scaling - Actual	59	$18	$0	$0	$0	$5	$49	$153	$211
LMS – Reported (PNNL)	57	$207	$0	$0	$0	$135	$608	$1,350	$2,295
LMS – Actual (PNNL)	70	$44	$0	$0	$0	$85	$125	$206	$673
LMS – Reported (In-Sample)	57	$76	$0	$0	$0	$49	$222	$494	$840
LMS – Actual (In-Sample)	70	$17	$0	$0	$0	$31	$48	$76	$246

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
HPwES									
Contingent Valuation	47	$78	-$3,000	$0	$0	$90	$600	$1,200	$3,000
Direct Scaling - Reported	55	$120	$0	$0	$0	$90	$500	$640	$960
Direct Scaling - Actual	80	$29	$0	$0	$8	$34	$87	$123	$206
LMS – Reported (PNNL)	58	$273	$0	$0	$0	$405	$1,215	$1,350	$1,688
LMS – Actual (PNNL)	93	$91	$0	$0	$81	$163	$232	$251	$278
LMS – Reported (In-Sample)	58	$100	$0	$0	$0	$148	$445	$494	$617
LMS – Actual (In-Sample)	93	$34	$0	$0	$30	$61	$85	$92	$102
Overall									
Contingent Valuation	201	$64	-$3,000	$0	$0	$0	$300	$500	$3,000
Direct Scaling - Reported	232	$76	$0	$0	$0	$15	$125	$300	$1,700
Direct Scaling - Actual	278	$16	$0	$0	$0	$8	$49	$96	$211
LMS – Reported (PNNL)	245	$177	$0	$0	$0	$135	$608	$1,350	$2,295
LMS – Actual (PNNL)	311	$45	$0	$0	$0	$85	$136	$206	$673
LMS – Reported (In-Sample)	245	$65	$0	$0	$0	$49	$222	$494	$840
LMS – Actual (In-Sample)	311	$17	$0	$0	$0	$31	$57	$76	$246

Table IV-8E compares the distribution of contingent valuations to responses to the question about the change in winter comfort. The median CV for those who said "much more comfortable" was considerably lower than the median value for those who said "somewhat more comfortable". However, the mean for those who said "much more comfortable" was higher than the mean for those who said "somewhat more comfortable", again showing the influence of extreme values.

Table IV-8E
Distribution of Contingent Valuations
By Reported Change in Winter Comfort

Change in Winter Comfort	#	Distribution of Contingent Valuations					
		Mean	Min	P25	Median	P75	Max
Much More Comfortable	23	$420	$3	$90	$200	$500	$3,000
Somewhat More Comfortable	13	$355	$20	$200	$480	$500	$600
No Change[1]	159	$0	$0	$0	$0	$0	$0
Somewhat Less Comfortable	5	-$709	-$3,000	-$350	-$100	-$84	-$10
Much Less Comfortable	1	-$500	-$500	-$500	-$500	-$500	-$500

[1]These participants were not asked to provide a contingent valuation; we assigned a contingent valuation of $0 based on their "no change" response.

Summer Comfort

Table IV-9A displays the percent of respondents who provided each type of valuation. The CV method had the highest percentage of participants with missing values, 42 percent of all respondents, due to the challenge of providing a dollar value. The LMS using actual bill changes had values from 80 percent of respondents. For each valuation method, participants with valuations of zero constituted a majority of participants with non-missing values.

Table IV-9A
Status of NEI Value by Method
Summer Comfort

NEI Value	Valuation Method									
	Contingent Valuation		Direct Scaling				Labeled Magnitude Scaling			
			Reported		Actual		Reported		Actual	
	#	%	#	%	#	%	#	%	#	%
Included Values										
• Positive	42	11%	39	10%	78	20%	40	10%	113	29%
• Negative	2	1%	0	0%	0	0%	0	0%	0	0%
• Zero	182	46%	201	51%	202	51%	207	53%	200	51%
All Included Values	226	58%	240	61%	280	71%	247	63%	313	80%
Missing	167	42%	153	39%	113	29%	146	37%	80	20%
Total	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**

Table IV-9B displays the number of respondents with sufficient information for each of the valuation methods for each participant group. The LMS method using actual savings values yielded the largest sample size, with 313 respondents. Methods using actual savings yielded larger sample sizes than those using reported savings because respondents were less likely to estimate a savings amount than they were to have the data necessary to calculate an actual estimate of that savings.

Table IV-9B
Number of Respondents per Valuation Method
Summer Comfort

Participant Group	Number of Respondents				
	Contingent Valuation	Direct Scaling		Labeled Magnitude Scaling	
		Reported	Actual	Reported	Actual
Thermostat Only	65	68	75	68	79
Water Heater Only	59	61	63	62	69
Heating System	49	54	63	58	73
HPwES	53	57	79	59	92

Participant Group	Number of Respondents				
	Contingent Valuation	Direct Scaling		Labeled Magnitude Scaling	
		Reported	Actual	Reported	Actual
All	**226**	**240**	**280**	**247**	**313**

Table IV-9C displays the weighted mean valuations of participants' change in summer comfort for all of the valuation methods. As expected, the HPwES participants had the highest valuations of their change in summer comfort, with values ranging from $38 to $302.

Table IV-9C
Annual Summer Comfort Valuation

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	$32	$7	$4	$13	$12	$5	$5
Water Heater Only	$1	$3	$2	$14	$12	$6	$5
Heating System	$60	$43	$12	$91	$44	$38	$18
HPwES	$126	$158	$39	$302	$92	$126	$38
All	**$61**	**$52**	**$14**	**$105**	**$45**	**$44**	**$19**

Table IV-9D displays the distribution of each summer comfort valuation to provide a more detailed comparison of the results from the various measurement approaches.

- Thermostat Only: No thermostat only respondents provided a negative value for summer comfort. The average was highest using the CV method, due to one large value of $1,200 provided by a thermostat only customer. The value was $0 for 95 percent of respondents using the DS method with reported bills and using the LMS method with reported bills and PNNL or in-sample multipliers.

- Water Heater Only: No water heater only respondents provided a negative value for summer comfort. As expected, most summer comfort values were zero, as the water heater is not expected to impact summer comfort.

- Heating System: The LMS with reported bills and PNNL multipliers yielded the highest valuation for these participants. While ten percent had a value over $324 using the LMS – Reported with PNNL multiplier approach, ten percent had a value over $132 using the LMS with actual bills and PNNL multipliers. The lowest valuation for heating system participants was -$5,000. The lowest average value among methods was obtained by using the DS method with actual bills, where 10 percent had a valuation over only $38. Differences were much larger in the upper tail of the distribution.

- HPwES: No respondents had a negative value for summer comfort for the HPwES participants. While ten percent had a valuation over $1,080 using the LMS-Reported approach, ten percent had a valuation over $500 using the CV approach, and ten percent had a valuation over $120 with the DS-Actual approach.

Table IV-9D
Distribution of Annual Summer Comfort Valuations
By Measures and Valuation Method

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
Thermostat Only									
Contingent Valuation	65	$32	$0	$0	$0	$0	$25	$100	$1,200
Direct Scaling - Reported	68	$7	$0	$0	$0	$0	$0	$0	$300
Direct Scaling - Actual	75	$4	$0	$0	$0	$0	$4	$47	$64
LMS – Reported (PNNL)	68	$13	$0	$0	$0	$0	$0	$0	$405
LMS – Actual (PNNL)	79	$12	$0	$0	$0	$0	$52	$94	$157
LMS – Reported (In-Sample)	68	$5	$0	$0	$0	$0	$0	$0	$170
LMS – Actual (In-Sample)	79	$5	$0	$0	$0	$0	$20	$39	$66
Water Heater Only									
Contingent Valuation	59	$1	$0	$0	$0	$0	$0	$0	$50
Direct Scaling - Reported	61	$3	$0	$0	$0	$0	$0	$0	$120
Direct Scaling - Actual	63	$2	$0	$0	$0	$0	$0	$5	$67
LMS – Reported (PNNL)	62	$14	$0	$0	$0	$0	$0	$0	$810
LMS – Actual (PNNL)	69	$12	$0	$0	$0	$0	$43	$91	$260
LMS – Reported (In-Sample)	62	$6	$0	$0	$0	$0	$0	$0	$340
LMS – Actual (In-Sample)	69	$5	$0	$0	$0	$0	$17	$38	$109
Heating System									
Contingent Valuation	49	$60	-$5,000	$0	$0	$50	$400	$500	$1,000
Direct Scaling - Reported	54	$43	$0	$0	$0	$2	$72	$100	$900
Direct Scaling - Actual	63	$12	$0	$0	$0	$3	$38	$50	$211
LMS – Reported (PNNL)	58	$91	$0	$0	$0	$0	$324	$608	$1,350
LMS – Actual (PNNL)	73	$44	$0	$0	$0	$85	$132	$187	$673
LMS – Reported (In-Sample)	58	$38	$0	$0	$0	$0	$136	$255	$567
LMS – Actual (In-Sample)	73	$18	$0	$0	$0	$36	$55	$78	$283

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
HPwES									
Contingent Valuation	53	$126	$0	$0	$0	$150	$500	$600	$1,200
Direct Scaling - Reported	57	$158	$0	$0	$0	$120	$720	$960	$1,250
Direct Scaling - Actual	79	$39	$0	$0	$11	$56	$120	$156	$206
LMS – Reported (PNNL)	59	$302	$0	$0	$0	$405	$1,080	$1,620	$1,688
LMS – Actual (PNNL)	92	$92	$0	$0	$72	$166	$232	$251	$278
LMS – Reported (In-Sample)	59	$126	$0	$0	$0	$170	$454	$680	$709
LMS – Actual (In-Sample)	92	$38	$0	$0	$30	$70	$97	$106	$117
Overall									
Contingent Valuation	226	$61	-$5,000	$0	$0	$25	$300	$500	$1,200
Direct Scaling - Reported	240	$52	$0	$0	$0	$0	$90	$300	$1,250
Direct Scaling - Actual	280	$14	$0	$0	$0	$4	$49	$84	$211
LMS – Reported (PNNL)	247	$105	$0	$0	$0	$0	$324	$810	$1,688
LMS – Actual (PNNL)	313	$45	$0	$0	$0	$85	$157	$205	$673
LMS – Reported (In-Sample)	247	$44	$0	$0	$0	$0	$136	$340	$709
LMS – Actual (In-Sample)	313	$19	$0	$0	$0	$36	$61	$86	$283

Table IV-9E compares the distribution of contingent valuations to responses about the change in summer comfort. The ordering of these values was generally as expected. For example, the mean and median for those who said "much more comfortable" were higher than for those who said "somewhat more comfortable".

Table IV-9E
Distribution of Contingent Valuations
By Reported Change in Summer Comfort

Change in Summer Comfort	#	Distribution of Contingent Valuations					
		Mean	Min	P25	Median	P75	Max
Much More Comfortable	24	$348	$0	$83	$200	$500	$1,200
Somewhat More Comfortable	19	$247	$15	$50	$120	$500	$1,000
No Change[1]	181	$0	$0	$0	$0	$0	$0
Somewhat Less Comfortable	2	-$2,584	-$5,000	-$5,000	-$2,584	-$168	-$168
Much Less Comfortable	0	-	-	-	-	-	-

[1]These participants were not asked to provide a contingent valuation; we assigned a contingent valuation of $0 based on their "no change" response.

Safety

Table IV-10A displays the percent of respondents who provided each type of valuation. The percentage of respondents missing values for the CV of change in safety was 29 percent, far lower than for the winter comfort and summer comfort NEIs, but almost all included values were zero. The LMS using actual bill changes had values from 82 percent of respondents.

Table IV-10A
Status of NEI Value by Method
Safety

NEI Value	Valuation Method									
	Contingent Valuation		Direct Scaling				Labeled Magnitude Scaling			
			Reported		Actual		Reported		Actual	
	#	%	#	%	#	%	#	%	#	%
Included Values										
• Positive	18	5%	24	6%	43	11%	27	7%	56	14%
• Negative	2	1%	0	0%	0	0%	0	0%	0	0%
• Zero	260	66%	272	69%	265	67%	275	70%	265	67%
All Included Values	280	71%	296	75%	308	78%	302	77%	321	82%
Missing	113	29%	97	25%	85	22%	91	23%	72	18%
Total	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**

[1]It was not possible to derive an in-sample multiplier for one respondent. When using the in-sample multipliers the number of positive values was 55 and the number of missing values was 73.

Table IV-10B displays the number of respondents with sufficient information for each of the valuation methods for each participant group. The LMS method using actual savings values yielded the largest sample size, with 321 respondents. Methods using actual savings yielded larger sample sizes than those using reported savings because respondents were less likely to estimate a savings amount than they were to have the data necessary to calculate an actual estimate of that savings.

Table IV-10B
Number of Respondents per Valuation Method
Safety

Participant Group	Number of Respondents				
	Contingent Valuation	Direct Scaling		Labeled Magnitude Scaling	
		Reported	Actual	Reported	Actual
Thermostat Only	78	81	81	82	82
Water Heater Only	63	66	68	67	70
Heating System	57	62	64	65	73

Participant Group	Number of Respondents				
	Contingent Valuation	Direct Scaling		Labeled Magnitude Scaling	
		Reported	Actual	Reported	Actual
HPwES	82	87	95	88	96
All	**280**	**296**	**308**	**302**	**321**

Table IV-10C displays the weighted mean valuations of safety for each valuation method. The lowest HPwES valuation was from the CV method, with an average value of -$10 due to a negative $4,000 response from one participant, again showing the sensitivity of this method to extreme values. The other valuation methods had relative valuations for the programs that were more in accordance with expectations. For example, the LMS method with reported savings and in-sample multipliers had a mean value of $62 for heating system participants and a mean value of $23 for HPwES participants.

Table IV-10C
Annual Safety Valuation

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	$18	$3	$1	$14	$6	$3	$1
Water Heater Only	$16	$7	$5	$16	$10	$8	$5
Heating System	$8	$88	$10	$124	$26	$62	$13
HPwES	-$10	$22	$10	$64	$28	$23	$9
All	**$7**	**$62**	**$9**	**$93**	**$23**	**$43**	**$11**

Table IV-10D displays the distribution of each safety valuation for each group to provide a more detailed comparison of the results from the various measurement approaches.

- Thermostat Only: No thermostat only participants provided a negative value for safety. The mean was highest using the LMS-reported bill with PNNL multipliers method, due to one large value of $405.

- Water Heater Only: No water heater only participants provided a negative value for safety. The vast majority of safety valuations were zero indicating that participants did not perceive an improvement in safety from the water heater replacement.

- Heating System: The LMS with reported bills and PNNL multipliers yielded the highest valuation for these participants. While ten percent had a value over $135 using the LMS – Reported with PNNL multiplier approach, ten percent had a value over $125 using the LMS with actual bills and PNNL multipliers. The lowest contingent valuation for heating system participants was -$5,000, which caused the average valuation to be among the lowest using the CV method.

- HPwES: The lowest contingent valuation for these participants was -$4,000, which caused the average valuation to be lowest using the CV method. While ten percent had a valuation over $33 using the LMS-Reported with PNNL multiplier approach, ten percent had a valuation over $153 using the LMS-Actual with PNNL multiplier approach.

Table IV-10D
Distribution of Annual Safety Valuations
By Measures and Valuation Method

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
Thermostat Only									
Contingent Valuation	77	$5	$0	$0	$0	$0	$0	$0	$200
Direct Scaling - Reported	81	$3	$0	$0	$0	$0	$0	$0	$200
Direct Scaling - Actual	81	$1	$0	$0	$0	$0	$0	$8	$20
LMS – Reported (PNNL)	82	$14	$0	$0	$0	$0	$0	$0	$405
LMS – Actual (PNNL)	82	$6	$0	$0	$0	$0	$0	$45	$157
LMS – Reported (In-Sample)	82	$3	$0	$0	$0	$0	$0	$0	$90
LMS – Actual (In-Sample)	81	$1	$0	$0	$0	$0	$0	$6	$35
Water Heater Only									
Contingent Valuation	63	$16	$0	$0	$0	$0	$0	$19	$500
Direct Scaling - Reported	66	$7	$0	$0	$0	$0	$0	$8	$300
Direct Scaling - Actual	68	$5	$0	$0	$0	$0	$4	$36	$144
LMS – Reported (PNNL)	67	$16	$0	$0	$0	$0	$0	$34	$810
LMS – Actual (PNNL)	70	$10	$0	$0	$0	$0	$44	$91	$194
LMS – Reported (In-Sample)	67	$8	$0	$0	$0	$0	$0	$17	$405
LMS – Actual (In-Sample)	70	$5	$0	$0	$0	$0	$22	$47	$97
Heating System									
Contingent Valuation	58	$12	-$5,000	$0	$0	$0	$100	$200	$1,000
Direct Scaling - Reported	62	$88	$0	$0	$0	$0	$100	$900	$1,700
Direct Scaling - Actual	64	$10	$0	$0	$0	$0	$43	$50	$153
LMS – Reported (PNNL)	65	$124	$0	$0	$0	$0	$135	$1,350	$2,295
LMS – Actual (PNNL)	73	$26	$0	$0	$0	$17	$125	$132	$215
LMS – Reported (In-Sample)	65	$62	$0	$0	$0	$0	$68	$675	$1,148
LMS – Actual (In-Sample)	73	$13	$0	$0	$0	$9	$62	$66	$107

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
HPwES									
Contingent Valuation	82	-$10	-$4,000	$0	$0	$0	$0	$0	$600
Direct Scaling - Reported	87	$22	$0	$0	$0	$0	$0	$90	$625
Direct Scaling - Actual	95	$10	$0	$0	$0	$0	$44	$70	$171
LMS – Reported (PNNL)	88	$64	$0	$0	$0	$0	$33	$405	$1,688
LMS – Actual (PNNL)	96	$28	$0	$0	$0	$0	$153	$163	$232
LMS – Reported (In-Sample)	88	$21	$0	$0	$0	$0	$8	$132	$550
LMS – Actual (In-Sample)	96	$9	$0	$0	$0	$0	$50	$53	$76
Overall									
Contingent Valuation	280	$9	-$5,000	$0	$0	$0	$25	$200	$1,000
Direct Scaling - Reported	296	$62	$0	$0	$0	$0	$80	$240	$1,700
Direct Scaling - Actual	308	$9	$0	$0	$0	$0	$43	$50	$171
LMS – Reported (PNNL)	302	$93	$0	$0	$0	$0	$135	$675	$2,295
LMS – Actual (PNNL)	321	$23	$0	$0	$0	$0	$116	$132	$232
LMS – Reported (In-Sample)	302	$45	$0	$0	$0	$0	$60	$264	$1,148
LMS – Actual (In-Sample)	320	$11	$0	$0	$0	$0	$53	$63	$107

Table IV-10E compares the distribution of contingent valuations to qualitative responses to the change in safety. Here, the valuations for the small number of respondents who provided a non-zero valuation corresponded as expected to the qualitative responses. The mean, median, minimum and maximum for those who said "much more comfortable" were all higher than for those who said "somewhat more comfortable".

Table IV-10E
Distribution of Contingent Valuations
By Reported Change in Safety

Change in Safety	#	Distribution of Contingent Valuations					
		Mean	Min	P25	Median	P75	Max
Much Safer	5	$432	$100	$200	$360	$500	$1,000
Somewhat Safer	13	$219	$1	$25	$100	$500	$600
No Change[1]	260	$0	$0	$0	$0	$0	$0
Somewhat Less Safe	1	-$4,000	-$4,000	-$4,000	-$4,000	-$4,000	-$4,000
Much Less Safe	1	-$5,000	-$5,000	-$5,000	-$5,000	-$5,000	-$5,000

[1]These participants were not asked to provide a contingent valuation; we assigned a contingent valuation of $0 based on their "no change" response.

Health

Table IV-11A displays the percent of respondents who provided each type of valuation. The percentage of respondents with a valuation of zero ranged from 77 percent to 80 percent, higher than for the other NEIs. Less than ten percent of respondents could estimate a change in health due to the program.

Table IV-11A
Status of NEI Value by Method
Health

NEI Value	Valuation Method									
	Contingent Valuation		Direct Scaling				Labeled Magnitude Scaling			
			Reported		Actual		Reported		Actual	
	#	%	#	%	#	%	#	%	#	%
Included Values										
• Positive	6	2%	12	3%	26	7%	14	4%	35	9%
• Negative	2	1%	0	0%	0	0%	0	0%	0	0%
• Zero	301	77%	309	79%	305	78%	313	80%	304	77%
All Included Values	309	79%	321	82%	331	84%	327	83%	339	86%
Missing	84	21%	72	18%	62	16%	66	17%	54	14%
Total	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**

Table IV-11B displays the number of respondents with sufficient information for each of the valuation methods for each participant group. The LMS method using actual savings values yielded the largest sample size, with 339 respondents. Methods using actual savings yielded larger sample sizes than those using reported savings because respondents were less likely to estimate a savings amount than they were to have the data necessary to calculate an actual estimate of that savings.

Table IV-11B
Number of Respondents per Valuation Method
Health

Participant Group	Number of Respondents				
	Contingent Valuation	Direct Scaling		Labeled Magnitude Scaling	
		Reported	Actual	Reported	Actual
Thermostat Only	81	84	84	85	85
Water Heater Only	68	69	75	69	76
Heating System	74	77	75	80	78
HPwES	86	91	97	93	100

Participant Group	Number of Respondents				
	Contingent Valuation	Direct Scaling		Labeled Magnitude Scaling	
		Reported	Actual	Reported	Actual
All	**309**	**321**	**331**	**327**	**339**

Table IV-11C displays the weighted mean valuations of participants' change in health for each valuation method. Except for the CV method, mean values were greatest for HPwES participants, with the highest mean value of $90 using the LMS with reported bills and PNNL multipliers. The mean heating system health value was $65 using this method.

Table IV-11C
Annual Health Valuation

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	-$123	$1	$2	$2	$5	$1	$2
Water Heater Only	$0	$1	$2	$1	$5	<$1	$2
Heating System	$20	$44	$4	$65	$11	$31	$6
HPwES	$3	$46	$8	$90	$21	$44	$10
All	**$3**	**$36**	**$4**	**$56**	**$11**	**$28**	**$6**

Table IV-11D displays the distribution of each health valuation for each group to provide a more detailed comparison of the results from the measurement approaches.

- Thermostat Only: The lowest contingent valuation among thermostat only participants was -$10,000. No respondent provided a positive contingent valuation for health, and less than ten percent of respondents had a positive value using any of the other approaches.

- Water Heater Only: No water heater only participants provided a negative value for health. Most health valuations were zero for water heater only participants.

- Heating System: No respondents provided a negative value for health for the heating system participants, but only a small proportion of respondents estimated a positive value for health. The LMS with reported bills and PNNL multipliers yielded the highest valuation for these participants. While five percent had a value over $169 using the LMS-Reported approach with PNNL multipliers, five percent had a value over $116 using the LMS with actual bills and PNNL multipliers.

- HPwES: The lowest contingent valuation for these participants was -$500. While ten percent had a valuation over $85 using the LMS-Actual approach with PNNL multipliers, less than ten percent had a positive valuation using the LMS-Reported approach with PNNL or in-sample multipliers.

Table IV-11D
Distribution of Annual Health Valuations
By Measures and Valuation Method

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
Thermostat Only									
Contingent Valuation	81	-$123	-$10,000	$0	$0	$0	$0	$0	$0
Direct Scaling - Reported	84	$1	$0	$0	$0	$0	$0	$0	$120
Direct Scaling - Actual	84	$2	$0	$0	$0	$0	$0	$0	$78
LMS – Reported (PNNL)	85	$2	$0	$0	$0	$0	$0	$0	$162
LMS – Actual (PNNL)	85	$5	$0	$0	$0	$0	$0	$47	$108
LMS – Reported (In-Sample)	85	$1	$0	$0	$0	$0	$0	$0	$78
LMS – Actual (In-Sample)	85	$2	$0	$0	$0	$0	$0	$23	$52
Water Heater Only									
Contingent Valuation	68	$0	$0	$0	$0	$0	$0	$0	$0
Direct Scaling - Reported	69	$1	$0	$0	$0	$0	$0	$0	$50
Direct Scaling - Actual	75	$2	$0	$0	$0	$0	$0	$5	$67
LMS – Reported (PNNL)	69	$1	$0	$0	$0	$0	$0	$0	$68
LMS – Actual (PNNL)	76	$5	$0	$0	$0	$0	$0	$65	$112
LMS – Reported (In-Sample)	69	$0	$0	$0	$0	$0	$0	$0	$33
LMS – Actual (In-Sample)	76	$2	$0	$0	$0	$0	$0	$31	$52
Heating System									
Contingent Valuation	74	$20	$0	$0	$0	$0	$0	$100	$500
Direct Scaling - Reported	77	$44	$0	$0	$0	$0	$0	$72	$1,700
Direct Scaling - Actual	75	$4	$0	$0	$0	$0	$0	$5	$86
LMS – Reported (PNNL)	80	$65	$0	$0	$0	$0	$0	$169	$2,295
LMS – Actual (PNNL)	78	$11	$0	$0	$0	$0	$0	$116	$206
LMS – Reported (In-Sample)	80	$32	$0	$0	$0	$0	$0	$82	$1,109
LMS – Actual (In-Sample)	78	$6	$0	$0	$0	$0	$0	$56	$100

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
HPwES									
Contingent Valuation	86	$3	-$500	$0	$0	$0	$0	$0	$600
Direct Scaling - Reported	91	$46	$0	$0	$0	$0	$0	$250	$1,000
Direct Scaling - Actual	97	$8	$0	$0	$0	$0	$24	$86	$114
LMS – Reported (PNNL)	93	$90	$0	$0	$0	$0	$0	$972	$1,688
LMS – Actual (PNNL)	100	$21	$0	$0	$0	$0	$85	$162	$232
LMS – Reported (In-Sample)	93	$43	$0	$0	$0	$0	$0	$470	$816
LMS – Actual (In-Sample)	100	$10	$0	$0	$0	$0	$41	$77	$112
Overall									
Contingent Valuation	309	$3	-$10,000	$0	$0	$0	$0	$100	$600
Direct Scaling - Reported	321	$36	$0	$0	$0	$0	$0	$63	$1,700
Direct Scaling - Actual	331	$4	$0	$0	$0	$0	$0	$33	$114
LMS – Reported (PNNL)	327	$56	$0	$0	$0	$0	$0	$169	$2,295
LMS – Actual (PNNL)	339	$11	$0	$0	$0	$0	$23	$116	$232
LMS – Reported (In-Sample)	327	$27	$0	$0	$0	$0	$0	$82	$1,109
LMS – Actual (In-Sample)	339	$6	$0	$0	$0	$0	$11	$56	$112

Table IV-11E compares the distribution of contingent valuations to qualitative responses about the change in health. Only eight respondents assigned a non-zero dollar value to the change in health, as the vast majority said there was no change.

Table IV-11E
Distribution of Contingent Valuations
By Reported Change in Health

Change in Family's Health	#	Distribution of Contingent Valuations					
		Mean	Min	P25	Median	P75	Max
Much Better	1	$200	$200	$200	$200	$200	$200
Somewhat Better	5	$356	$80	$100	$500	$500	$600
No Change[1]	301	$0	$0	$0	$0	$0	$0
Somewhat Worse	1	-$500	-$500	-$500	-$500	-$500	-$500
Much Worse	1	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000	-$10,000

[1]These participants were not asked to provide a contingent valuation; we assigned a contingent valuation of $0 based on their "no change" response.

Noise

Table IV-12A displays the percent of respondents who provided each type of valuation. The CV method has the highest percentage of respondents with missing values, 39 percent of all

respondents. The LMS using actual bill changes had values from 84 percent of respondents. For each valuation method, participants with valuations of zero constituted a majority of participants with non-missing values.

Table IV-12A
Status of NEI Value by Method
Noise

NEI Value	Valuation Method									
	Contingent Valuation		Direct Scaling				Labeled Magnitude Scaling			
			Reported		Actual		Reported		Actual	
	#	%	#	%	#	%	#	%	#	%
Included Values										
• Positive	16	4%	29	7%	57	15%	38	10%	96	24%
• Negative	1	<1%	0	0%	0	0%	0	0%	0	0%
• Zero	223	57%	250	64%	253	64%	252	64%	234	60%
All Included Values	240	61%	279	71%	310	79%	290	74%	330	84%
Missing	153	39%	114	29%	83	21%	103	26%	63	16%
Total	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**	**393**	**100%**

Table IV-12B displays the number of respondents with sufficient information for each of the valuation methods for each participant group. The LMS method using actual savings values yielded the largest sample size, with 330 respondents. Methods using actual savings yielded larger sample sizes than those using reported savings.

Table IV-12B
Number of Respondents per Valuation Method
Noise

Participant Group	Number of Respondents				
	Contingent Valuation	Direct Scaling		Labeled Magnitude Scaling	
		Reported	Actual	Reported	Actual
Thermostat Only	80	84	86	84	88
Water Heater Only	43	52	63	56	68
Heating System	43	59	66	61	71
HPwES	74	84	95	89	103
All	**240**	**279**	**310**	**290**	**330**

Table IV-12C displays the weighted mean valuations of participants' change in noise level for all valuation methods. As expected, the thermostat only participants had very low valuations

of the change in noise, ranging from $0 to $6. Heating system participants had valuations ranging from $15 to $166.

Table IV-12C
Annual Noise Valuation

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	$0	<$1	$1	$3	$6	$1	$1
Water Heater Only	$16	$4	$5	$23	$21	$6	$5
Heating System	$49	$92	$16	$166	$40	$66	$15
HPwES	$15	$51	$12	$99	$47	$39	$16
All	**$36**	**$68**	**$13**	**$126**	**$36**	**$49**	**$13**

Table IV-12D displays the distribution of each noise valuation for each group to provide a more detailed comparison of the results from the various measurement approaches.

- Thermostat Only: As expected, every thermostat only customer gave a contingent valuation of $0 for the change in noise level. Less than five percent of respondents had a positive value using the LMS-Reported approach, and ten percent of respondents had a positive value using the LMS-Actual approach.

- Water Heater Only: No respondents provided a negative value for noise for the water heater only participants. While 25 percent of respondents had a value over $30 using the LMS-Actual with PNNL multiplier approach, less than ten percent had positive values using the DS-Reported approach.

- Heating System: LMS with reported bills yielded the highest valuation for these participants, an average of $166. While 25 percent had a value over $108 using the LMS-Reported with PNNL multiplier approach, 25 percent had a value over $5 using the DS method with actual bills.

- HPwES: The highest mean valuation was $99 with the LMS-Reported with PNNL multiplier approach. While ten percent had a valuation over $162 using the LMS-Actual with PNNL multiplier approach, less than ten percent had a positive valuation using the CV approach.

Table IV-12D
Distribution of Annual Noise Valuations
By Measures and Valuation Method

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
Thermostat Only									
Contingent Valuation	80	$0	$0	$0	$0	$0	$0	$0	$0
Direct Scaling - Reported	84	$0	$0	$0	$0	$0	$0	$0	$15
Direct Scaling - Actual	86	$1	$0	$0	$0	$0	$0	$0	$35
LMS – Reported (PNNL)	84	$3	$0	$0	$0	$0	$0	$0	$203
LMS – Actual (PNNL)	88	$6	$0	$0	$0	$0	$0	$39	$247
LMS – Reported (In-Sample)	84	$1	$0	$0	$0	$0	$0	$0	$63
LMS – Actual (In-Sample)	88	$1	$0	$0	$0	$0	$0	$6	$77
Water Heater Only									
Contingent Valuation	43	$16	$0	$0	$0	$0	$10	$150	$300
Direct Scaling - Reported	52	$4	$0	$0	$0	$0	$0	$24	$120
Direct Scaling - Actual	63	$5	$0	$0	$0	$0	$16	$39	$72
LMS – Reported (PNNL)	56	$23	$0	$0	$0	$0	$10	$135	$810
LMS – Actual (PNNL)	68	$21	$0	$0	$0	$30	$67	$103	$260
LMS – Reported (In-Sample)	56	$6	$0	$0	$0	$0	$1	$12	$253
LMS – Actual (In-Sample)	68	$5	$0	$0	$0	$3	$18	$32	$81
Heating System									
Contingent Valuation	43	$32	-$100	$0	$0	$0	$100	$500	$500
Direct Scaling - Reported	59	$92	$0	$0	$0	$16	$100	$900	$1,700
Direct Scaling - Actual	66	$16	$0	$0	$0	$5	$52	$77	$211
LMS – Reported (PNNL)	61	$166	$0	$0	$0	$108	$324	$1,350	$2,295
LMS – Actual (PNNL)	71	$40	$0	$0	$0	$53	$153	$211	$285
LMS – Reported (In-Sample)	61	$66	$0	$0	$0	$33	$130	$541	$919
LMS – Actual (In-Sample)	71	$15	$0	$0	$0	$21	$53	$85	$114

Group, Method	#	Distribution of NEI Value							
		Mean	Min	P25	Median	P75	P90	P95	Max
HPwES									
Contingent Valuation	74	$15	$0	$0	$0	$0	$0	$200	$500
Direct Scaling - Reported	84	$51	$0	$0	$0	$0	$5	$600	$875
Direct Scaling - Actual	95	$12	$0	$0	$0	$0	$38	$84	$154
LMS – Reported (PNNL)	89	$99	$0	$0	$0	$0	$120	$972	$1,688
LMS – Actual (PNNL)	103	$47	$0	$0	$0	$97	$162	$208	$252
LMS – Reported (In-Sample)	89	$37	$0	$0	$0	$0	$32	$389	$676
LMS – Actual (In-Sample)	103	$16	$0	$0	$0	$32	$56	$65	$101
Overall									
Contingent Valuation	240	$25	-$100	$0	$0	$0	$50	$200	$500
Direct Scaling - Reported	279	$68	$0	$0	$0	$0	$72	$500	$1,700
Direct Scaling - Actual	310	$13	$0	$0	$0	$4	$49	$63	$211
LMS – Reported (PNNL)	290	$126	$0	$0	$0	$0	$324	$810	$2,295
LMS – Actual (PNNL)	330	$36	$0	$0	$0	$51	$132	$187	$285
LMS – Reported (In-Sample)	290	$49	$0	$0	$0	$0	$130	$270	$919
LMS – Actual (In-Sample)	330	$13	$0	$0	$0	$14	$46	$75	$114

Table IV-12E compares the distribution of contingent valuations to qualitative responses about the change in noise level. Only 20 respondents assigned a dollar value to this change, roughly in line with the qualitative response order.

Table IV-12E
Distribution of Contingent Valuations
By Reported Change in Noise Level

Change in Noise Level	#	Distribution of Contingent Valuations					
		Mean	Min	P25	Median	P75	Max
Much Less Noisy	8	$217	$10	$63	$150	$400	$500
Somewhat Less Noisy	11	$193	$0	$0	$150	$500	$500
No Change[1]	220	$0	$0	$0	$0	$0	$0
Somewhat Noisier	1	-$100	-$100	-$100	-$100	-$100	-$100
Much Noisier	0	-	-	-	-	-	-

[1]These participants were not asked to provide a contingent valuation; we assigned a contingent valuation of $0 based on their "no change" response.

D. NEI Method Assessment

This section discusses the advantages and disadvantages of the NEI estimation methods in the context of this analysis.

Comparison of Scaling Methods and Contingent Valuation

One of the main disadvantages of the CV method was that few respondents provided values, and those who did often provided extreme values. The number of participants who had sufficient information for each valuation method was consistently lowest for the CV method and the mean valuations were influenced by a small number of responses.

On an individual level, participants were often inconsistent in how they answered the questions regarding a given NEI. It was common for respondents to provide a CV dollar value that was not at all close to the number obtained by multiplying reported bill savings by the percentage value they provided. For example, one respondent said they had no bill savings, an improvement in winter comfort with a value of $500, and a change in winter comfort equivalent to 10 percent of their bill savings. Another respondent said bill savings were $100, the winter comfort improvement value was $100, and that the change in winter comfort was equivalent to 50 percent of bill savings. These were somewhat common occurrences in the survey data and place uncertainty on the usefulness of the valuation methods.

Compared to scaling methods, this survey placed fewer restrictions on the CV valuations. In addition to allowing negative valuations, there were no ceilings and floors as there were with the multipliers. The major disadvantage of the CV method is that its open-ended nature yields volatile and inconsistent valuations, and the prompt is difficult for some respondents to answer. Therefore, we agree with statements in the literature that, when used alone, the disadvantages of CV make it too unstable to be a reliable indicator of NEI value.[26] However, in conjunction with other methods, CV may add valuable information.

Comparison of Direct Scaling and Labeled Magnitude Scaling

The DS method consistently produced lower estimates than the LMS method. Typically, those who responded to the LMS question said they valued NEIs more than their bill savings. In contrast, the DS question limited respondents to provide a value between 0 and 100 percent of their bill savings. If respondents correctly understood the DS method, we expect that most of those who said the NEI was more valuable than their bill savings would provide the maximum response of 100 percent. However, for each of the five NEIs, the mean percentage for those who said the NEI was more valuable was at or below the less valuable PNNL LMS multiplier of 0.65. It is possible that these respondents understood the question to mean they were valuing the NEI at, for instance, ten percent *more than* bill savings rather than ten percent *of* bill savings. More in-depth research with participants should be conducted to further understand these measurement issues.

[26] Clendenning, et al. 2012, *op. cit.* See also: Hausman, J. 2012. "Contingent valuation: from dubious to hopeless." *Journal of Economic Perspectives, 26*(4), 43-56. See also: Kahneman, D., Ritov, I., Jacowitz, K. E., & Grant, P. 1993. "Stated willingness to pay for public goods: A psychological perspective." *Psychological Science, 4*(5), 310-315.

Respondents who said that the value of NEIs was the same as or less than their energy savings tended to provide lower values for the DS question than those who said it was of more value (although with significant overlap). However, the DS responses again provided lower multipliers than the LMS method, even though in these cases it was possible for them to provide DS values equal to the LMS multipliers (between zero percent and 100 percent).

When asked to value the NEI as a percentage of energy savings, there was clustering at low values (ten percent or 20 percent), at the middle value of 50 percent, and at the extremes (zero and 100 percent).

The DS multipliers may be underestimated given the restrictions we placed, limiting responses to 100 percent of the energy value. This was an intentional design, to create more reasonable valuations than are sometimes seen. However, we will consider removing this restriction in future research.

Comparison of Reported and Actual Bill Savings Values

Reported bill savings resulted in higher estimates of NEI values than actual bill savings. This occurred because some respondents reported savings that were much higher than those measured in the data. The distributions of reported and actual bill savings therefore differed greatly, with more extreme values for reported savings. In statistical terms, this resulted in a much more right-skewed distribution of reported savings compared to actual savings, and a significantly higher mean for the reported savings. This was true even after dropping the most extreme outliers.

Many respondents reported that they did not see a change in their energy bills and therefore had a reported bill savings value of $0. However, actual bill changes were of course always non-zero, whether or not that change was due to the installed measures. This is important because the NEI scaling method estimates were $0 when reported bill savings were zero (or less than zero).

The major disadvantage of using actual bill savings values is that when respondents value the NEI relative to savings, they are valuing it compared to what they believe the savings were, as opposed to the actual value of the savings. For example, an individual who estimated zero bill savings should say that they value the NEI more than their bill savings if they received any value from the NEI. However, if they were aware that their actual bill savings were substantial, they might say that the value of the NEI was lower. Therefore, the accuracy of the assigned multipliers may be lower when using actual savings if the respondent did not have an accurate perception of the bill savings. This is important because NEI studies often attempt to apply multipliers from previous studies to actual bill savings estimates when these studies do not include a participant survey.

E. Estimated Non-Energy Impacts

Table IV-13 displays the estimated value of the five NEIs by participant group, using the methods that provided the lowest and highest NEI valuations. The estimated winter comfort NEI values for HPwES participants ranged from $29 to $273, while the values for heating

system participants ranged from $18 to $207. This large difference demonstrates the sensitivity of the estimates to research methodology.

Table IV-13
Estimated Annual Non-Energy Impacts
By Participant Group

Participant Group	Average Valuation									
	Direct Scaling – Actual					Labeled Magnitude Scaling Reported Savings, PNNL Multipliers				
	Winter Comfort	Summer Comfort	Safety	Health	Noise	Winter Comfort	Summer Comfort	Safety	Health	Noise
Thermostat Only	$6	$4	$1	$2	$1	$23	$13	$14	$2	$3
Water Heater Only	$1	$2	$5	$2	$5	$1	$14	$16	$1	$23
Heating System	$18	$12	$10	$4	$16	$207	$91	$124	$65	$166
HPwES	$29	$39	$10	$8	$12	$273	$302	$64	$90	$99
Total	**$16**	**$14**	**$9**	**$4**	**$13**	**$177**	**$105**	**$93**	**$56**	**$126**

Table IV-14 compares the expected NEI values and the estimated NEI value ranges. Various levels of impacts are expected based on the specific measures installed. The table shows that the estimated value orderings match expectations for the most part.

- Winter Comfort: Water heaters are not expected to impact winter comfort, thermostats may have a small impact, heating systems may have a medium impact for those whose replaced systems were no longer working well, and HPwES should have a large impact due to the air sealing and insulation, possibly in combination with a new heating system.

- Summer Comfort: Water heaters are not expected to impact summer comfort, thermostats may have a small impact, heating systems also can include air conditioning replacement, so they may have a medium impact for those whose replaced failing air conditioning systems, and HPwES should have a large impact due to the air sealing and insulation, possibly in combination with a new air conditioning system.

- Safety: Thermostats are not expected to impact safety. Water heaters may have a medium impact on safety because gas water heaters are a combustion appliance, HPwES may have a medium impact on safety as participants may only have air sealing and insulation and not a new heating system, and a heating system is expected to have the largest impact on safety.

- Health: Thermostats and water heaters are expected to have a low impact on health, heating systems a medium impact, and HPwES a large impact because the air sealing and insulation can improve the winter and summer temperature in the home.

- Noise: Thermostats and water heaters are not expected to impact noise. Heating systems may have a low impact and HPwES may have a medium impact on noise.

Table IV-14
NEI Comparison to Expectation

Participant Group	Expected and Estimated Annual NEI Values									
	Winter Comfort		Summer Comfort		Safety		Health		Noise	
	Expect	Estimate	Expect	Estimate	Expect	Estimate	Expect	Estimate	Expect	Estimate
Thermostat	Low	$6-$38	Low	$4-$32	None	$1-$18	Low	-$123-$5	None	$0-$6
Water Heater	None	$0-$12	None	$1-$14	Med	$5-$16	Low	$0-$5	None	$4-$23
Heating	Med	$17-$207	Med	$12-$91	High	$8-$124	Med	$4-$65	Low	$15-$166
HPwES	High	$29-$273	High	$38-$302	Med	-$10-$64	High	$3-$90	Med	$12-$99

Table IV-15 displays our preferred and recommended set of NEI multipliers this study. Across the five NEIs, the table shows a total NEI value of $19 for thermostat only participants, $21 for water heater only participants, $273 for heating system participants, and $332 for HPwES participants.

The LMS method with reported bill savings and in-sample multipliers was selected for the following reasons.

- Participant Response: This method makes use of participant responses on estimated bill savings, NEI value compared to bill savings, and a qualitative comparison of the value of the NEI to the bill savings. It does not make use of the most unreliable piece of information – the CV direct estimate of NEI value.
- Bill Savings: The estimate uses the participant's estimate of bill savings, as they are valuing the NEI compared to that level, as opposed to the actual bill savings which they do not know.
- Multiplier: The estimate uses the in-sample multiplier, which is derived from program participant's experience, as opposed to using the PNNL multiplier, which is arbitrarily developed based on an unrelated previous study.
- NEI Value: The estimates are on the lower end of the methods and provide what we believe is a justifiable value for most of the NEIs.

However, there remain important uncertainties around these results.

- Reported Savings: These values could overestimate NEIs in some cases because of inflated reports by some respondents.
- In-Sample Multipliers: These multipliers may be less accurate if respondents were confused about how to assign a value as a percent of their bill savings.
- LMS Interpretation: The in-sample multipliers were not consistent with the literal interpretation of the LMS question. For example, the multipliers for "more value" were less than one.
- Health and Safety Impacts: Respondents may lack the knowledge to accurately assess how these have changed as result of the program.

- Negative Valuations: The LMS method does not allow for negative valuations, so it may overestimate the value of NEIs if there were substantial negative impacts for some participants.

Table IV-15
Mean Annual NEI Values for Selected NEI Estimation Method
LMS with Reported Bill Savings and In-Sample Multipliers

Participant Group	Non-Energy Impact					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**

F. Summary

We asked resident energy efficiency program participants to value the Non-Energy Impacts (NEIs) associated with the work done in their home, which was a thermostat only, a water heater only, a heating system with or without an air conditioning system, and air sealing and/or insulation with or without a heating system and/or an air conditioning system. Using multiple calculation methods, we obtained estimates of the NEIs for the participants who provided sufficient data.

Our recommended method is the LMS with 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 a reasonable value for most of the NEIs.

The total value of the five estimated NEIs were $19 for thermostat only participants, $21 for water heater only participants, $273 for heating system participants, and $332 for HPwES participants. The heating system participants had the highest NEI for the winter comfort improvement, a value of $76. The HPwES participants had the highest NEI value for summer comfort improvement, a value of $126.

V. Findings & Recommendations

This section summarizes the findings on the NEIs associated with the program and provides recommendations for future NEI research.

A. Key Findings

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. The estimated value orderings from this study matched expectations for relative valuations in most cases. Participants who received heating system replacements and HPwES had the greatest NEI values for winter comfort, summer comfort, safety, health, and noise.

We recommend using the LMS with 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 a reasonable value for most of the NEIs.

The total value of the five estimated NEIs was $19 for thermostat only participants, $21 for water heater only participants, $273 for heating system participants, and $332 for HPwES participants. The heating system participants had the highest NEI for the winter comfort improvement, a value of $76. The HPwES participants had the highest NEI value for summer comfort improvement, a value of $126.

B. Recommendations

Based on these findings, 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.