Energy Savings Assistance Program

Non-Energy Impacts Study

CALMAC ID: SCE0498.01

Final Report

Submitted by Evergreen Economics

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1 Executive Summary

The California Investor-Owned Utilities (IOUs) and the California Public Utilities Commission (CPUC) Energy Division (ED), jointly referred to as the Study Team, engaged Evergreen Economics ("research team") to develop updated non-energy impact (NEI) values for health, comfort, and safety (HCS) benefits from the statewide Energy Savings Assistance (ESA) program. The CPUC directed the IOUs in Decision 21-06-015 to form the ESA Cost-Effectiveness Sub-Working Group ("Subgroup") to lead the development of a study on NEIs. The Subgroup developed the scope for this study to estimate updated NEI values for the ESA program. The study objectives were to:

- Determine if and how often ESA participants experience certain HCS-related benefits
- Identify which improvements can be attributed to ESA program measures
- Estimate monetary values for studied HCS benefits
- Estimate impacts from ESA participation of the studied HCS benefits

Methods and Approach

The research team conducted both secondary and primary research, including a literature review and an online web survey of low-income households in California. Based on the literature review, the study focused on five key HCS-related metrics that ESA treatments (including weatherization, heating and cooling equipment repair and appliance replacement) might affect:

- Comfort during winter months
- Comfort during summer months
- Reduction in home draftiness
- Improvement in indoor air quality
- Reduction in noise (from both appliances and external sources)

The ESA Program's cost effectiveness tool includes separate participant NEI estimates for health, comfort, safety and noise. This study focused on updating the valuations for the comfort and noise NEIs, with a more limited assessment of health NEIs (including air quality); the study did not address safety due to concerns with valuing safety through a survey-based research approach.

The research team surveyed a representative sample of 865 ESA participants and 438 nonparticipant low-income households as a comparison group to assess changes in these five metrics and to explore their value.

The researchers designed the survey through a multi-step development process, including literature review, survey design, pre-testing with 40 ESA participants, in-depth follow-up interviews with 27 pre-test participants, and final revisions to the survey guide based on pre-test findings. Respondents completed the survey in either English or Spanish based on their preference.

The research team analyzed participant and comparison group survey data to develop estimates of how often ESA treatment results in comfort, noise and air quality[1] benefits, separating program impacts from factors like differences in weather, outdoor pollutants, and occupant behavior between 2023 and 2024.

The researchers used the results of a conjoint analysis based on survey responses to estimate the monetary value of comfort, noise and air quality benefits. This approach showed respondents pairs of scenarios with five different features, including comfort, noise and air quality conditions, along with monthly bill credits. Survey respondents selected which of the two scenarios they preferred based on the features (see Table 1 in Section 3.3 for an example of the scenario choice exercise). By analyzing these choices, researchers were able to estimate how much bill credit customers would trade for specific improvements.

By combining how often benefits occur with their values and weighting based on typical measure combinations in ESA (in program years 2023 and Q1 2024), the research team extrapolated the results of this study to estimate average first year comfort, noise and air quality benefits values for the program.[2]

The research team also investigated whether ESA participants reported improvements in symptoms related to chronic health conditions[3] that they attribute to ESA Program treatments.

Summary of Conclusions

Based on analysis of the participant and comparison group survey data, the study found that **ESA treatments in 2023 and Q1 2024 led to noticeable comfort, noise and air quality impacts for a portion of participant households**. While most ESA participants noticed no improvement in the comfort, noise or air quality levels in their home between 2023 and 2024, statistically significant proportions of homes did notice changes that they attributed to ESA measures.

Key findings include:

- Overall, 12 percent of all surveyed ESA participants noticed one or more improvements in comfort, noise or air quality that they attributed in part to ESA participation.

[1] Improved air quality is a component of ESA's health NEI category.
[2] The study does not address NEI persistence.
[3] The conditions included asthma, arthritis, COPD, and autoimmune diseases (e.g., Lupus, MS).

- 18 percent of ESA participants who received major heating-related measures reported improved winter comfort, with 58 percent of that improvement attributed to ESA measures.
- 17 percent of recipients who received major cooling-related measures reported improved summer comfort, with 46 percent coming from ESA.
- 14 percent of participants receiving major draftiness-related measures reported draftiness improvements, and 73 percent of that improvement attributable to ESA measures.
- 9 percent of participants receiving major air quality-related measures reported indoor air quality improvements, with 31 percent directly coming from ESA-installed measures.
- 6 percent of participants receiving applicable measures reported noise reduction benefits.

The study also found that participants value comfort, noise and air quality benefits (when they occur), with valuations ranging from approximately $129 per year (for indoor air quality) to $242 per year for winter and summer comfort based on the participant conjoint analysis results.

Since ESA participation leads to impacts for a subset of participant households (and not all households), the full value of the impact is applied proportional to the impact. The result is that the average ESA participant in 2023 and Q1 2024 received approximately $9 per year in comfort-related NEIs, $1 per year in air quality-related NEIs, and $1 per year in noise-related NEIs.

The study found that there was no meaningful impact of ESA treatments on the symptoms experienced by households affected by the chronic health conditions covered in the study.

Study Limitations

Important limitations of the study include:

- Reliance on self-reported survey data introduces challenges including recall bias, difficulty attributing changes to specific causes, and potential shifts in perceptions if participants were re-surveyed.
- Methodological constraints in the conjoint analysis include predetermined attribute levels that may not capture all participant experiences and assumptions that participants value each dollar equally regardless of their income level, which may not be accurate.
- Precision of benefit estimates is affected by limited sample sizes for certain subgroups and measure combinations, constraining conclusions about specific segments.
- Important impacts fell outside the study's scope, including safety issues (fire hazards, carbon monoxide poisoning) and comprehensive health assessments, due to survey length constraints and privacy concerns.

Despite these limitations, the study provides valuable insights while acknowledging the inherent complexities of quantifying NEIs resulting from participation in low-income energy efficiency programs.

Considerations for Future Research

This study focused on estimating the comfort, noise and air quality NEI values from ESA Program participation, and did not address all potential participant NEIs, including:

- Home safety outcomes, such as reduced risk of fire hazards, carbon monoxide poisoning, or trip and fall incidents.
- Comprehensive participant health impacts, including changes in frequency or severity of colds, flus, and allergies.

These excluded non-energy impacts represent important areas for future research that would provide a more comprehensive understanding of the full benefits of the ESA program. Subsequent research should consider methods beyond customer surveys due to the challenges addressing home safety and granular health impacts.

2 Introduction – Background and Objectives

The Evergreen Economics research team (Evergreen Economics and associates, NMR Group, and Ewald & Wasserman) conducted the 2025 Energy Savings Assistance (ESA) Program Non-Energy Impacts (NEI) Study on behalf of the Study Team, consisting of the joint California investor-owned utilities (IOUs) and the Energy Division of the California Public Utilities Commission (CPUC). The Study Team directed the study and provided review and input throughout the course of the study.

California's ESA Program is a statewide, ratepayer-funded initiative that provides no-cost direct installation of weatherization services and energy efficiency measures to eligible low-income households.[4] Initiated in the 1980s as the Low Income Energy Efficiency (LIEE) Program and administered by California's four IOUs—Southern California Edison (SCE), Pacific Gas & Electric (PG&E), Southern California Gas Company (SoCalGas), and San Diego Gas & Electric (SDG&E)—the program was originally modeled after federal assistance programs designed to help low income customers save money on their energy bills by providing more efficient measures and weatherization services to customers residing in cold climates who may otherwise be unable to afford sufficient heat.[5]

The ESA Program is intended to reduce energy bills by providing weatherization and energy-efficient measures that customers could not otherwise afford. In addition to reducing energy costs, the program also aims to improve participants' health, comfort, and safety (HCS) and support the achievement of California's greenhouse gas reduction targets. Reliable assessments of non-energy impacts have become increasingly important to understanding the overall benefits of ESA to program participants.

Non-Energy Impacts (NEIs) fall into three primary categories based on their main beneficiaries: utility impacts, participant impacts, and societal impacts.[6] For the ESA Program, participant impacts—specifically those related to health, comfort, and safety—have been central to justifying the offered measures. The ESA Program's cost effectiveness tests have incorporated non-energy impacts since the early 2000s from an NEI tool originally created for the predecessor to ESA, the LIEE Program.

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[4] ESA defines low-income as up to 250% of the Federal Poverty Guidelines (https://www.cpuc.ca.gov/consumer-support/financial-assistance-savings-and-discounts/energy-savings-assistance)

[5] https://www.energy.gov/scep/wap/weatherization-assistance-program

[6] Skumatz Economic Research Associates, Inc., Non-Energy Benefits Study for the Low Income Energy Efficiency Program, September 2009. https://liob.cpuc.ca.gov/wp-content/uploads/sites/14/2020/12/Non-Energy-Benefits-Study-SERA-Inc-2010.pdf.

In 2019, the IOUs commissioned a study[7] to update the NEI calculations and model. However, a subsequent study finalized in 2021[8] examined the 2019 study's source data and identified concerns, including relying on secondary sources from outside of California to inform non-energy impacts (given California's relatively mild climate relative to the climates of the studied jurisdictions).

Subsequently, the CPUC (in Decision 21-06-015) directed the IOUs to conduct an NEI study, which was directed by the ESA Cost-Effectiveness Sub-Working Group ("Subgroup") to estimate new NEI values for HCS impacts that are:

1. Derived from current survey data from ESA participants.
2. Specific to California's ESA program's residential measures.[9]
3. Based on transparent and defensible analytical methods for estimating non-market valuations (i.e., the value of goods or services that are not typically bought or sold).

This study sought to estimate current NEI values for HCS improvements attributable to the statewide ESA program through primary research with California households. The objectives of the study were to:

1. Determine which HCS-related NEIs are addressable through primary research with ESA participants.
2. Understand the extent to which the NEIs are realized by ESA participants following their participation in the program.
3. Determine the extent to which realization of these NEIs may be attributed to the ESA measures provided.
4. Develop monetary values for the NEIs resulting from the program.
5. Estimate the average value of the NEIs from ESA participation.

The study relied on two methods used to develop monetary values for non-market goods and services like comfort, noise and air quality impacts. These stated preference methods are widely

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[7] Skumatz Economic Research Associates, Inc. and Navigant Consulting Inc., Non-Energy Benefits and Non-Energy Impact (NEB/NEI) Study for the California Energy Savings Assistance (ESA) Program, Volumes 1 and 2, August 2019.
https://pda.energydataweb.com/api/view/2289/ESA%20NEB%20Study%20Draft%20Report%20Volume1.pdf

[8] APPRISE Inc., California Energy Savings Assistance Program Non-Energy Benefits Final Report, January 2021.
https://pda.energydataweb.com/api/view/2471/Final%20CA%20ESA%20NEB%20Report%201-25-21_.pdf

[9] The study focused on residential in-home measures—and not measures installed in common areas of multifamily properties—to get meaningful results (i.e., sufficient sample sizes within the budget allocated to surveys and incentives).

used to determine resource and product feature values, including to explore the value of non-energy impacts.

3 Methodology

The study involved a review of available literature to inform the study and survey design, which was followed by primary data collection via a web survey of ESA participants and a comparison group of nonparticipant low-income households. The analysis included estimation of the frequency ESA participants receive certain HCS benefits and a conjoint analysis to estimate monetary values.

3.1 Literature Review and Study Design

The research team conducted a literature review to identify the types of HCS-related benefits considered relevant to energy efficiency and weatherization programs (like ESA). The literature review determined that the most relevant HCS impacts that may result from ESA program participation include:

- Increased comfort in winter
- Increased comfort in summer
- Improved air quality
- Reduction in noise
- Health impacts (e.g., frequency/intensity of colds, effects on asthma, allergies, arthritis)
- Changes in humidity or dampness
- Change in the presence of mold
- Home safety

The literature review also investigated research methods and approaches used in other relevant NEI studies. The review included studies conducted in the past 10-15 years and those specifically looking at how other research had used the contingent valuation methods (i.e., willingness to pay, willingness to accept) and conjoint analysis approaches to quantify NEIs.

3.1.1 Selection of HCS Metrics to Examine

Based on the literature review and the direction to estimate new NEI values based on current survey data from ESA participants, the research team and Study Team determined that this NEI study should focus on HCS benefits that may result when participants receive ESA measures ***and*** that participant surveys could realistically address. The metrics are grouped based on broader NEI categories included in the IOU's ESA cost effectiveness calculators and include:

- Participant comfort:
    - Increased comfort in winter

    - Increased comfort in summer
    - Reduced draftiness
- Reduced noise in homes:
    - Noise reduction from indoor sources (new/repaired appliances or HVAC measures)
    - Noise reduction from outside sources (from building shell measures)
- Participant health:[10]
    - Improved indoor air quality
    - Symptom improvement among household members with chronic health conditions

Safety-related NEIs were excluded from the list of metrics covered by this study because of the difficulty incorporating safety-related impact questions into primary research with program participants. The study does include an examination of health-related NEIs but does not provide a comprehensive health-specific NEI valuation as the primary research conducted is not inclusive of all potential health benefits (only air quality benefits and symptom improvement for certain chronic health conditions).

3.1.2 Selection of Measure Groups to Examine

The study addressed all ESA measures, oversampling for larger and more expensive measures (such as replacing or repairing cooling and heating equipment). Some of these larger measures have low (or no) energy savings and have been included in the ESA program measure mix as they are assumed to lead to HCS improvements based on research from other regions.

The study grouped ESA measures into the following five categories:

Measure Group 1 (Basic): Lighting, simple water saving measures (low-flow)

Measure Group 2 (Enclosure): Air sealing, attic/ceiling insulation, window/door repair or replacement

Measure Group 3 (Non-Weather Sensitive Appliances): Water heater repair or replacement, refrigerators, other appliances

Measure Group 4 (Heating): Furnace repair or replacement, duct sealing, smart thermostats

Measure Group 5 (Cooling): Central AC, room AC, evaporative cooler, portable AC (replacement or installation of any) and AC tune-ups, duct sealing, smart thermostats

[10] Not all aspects of the health NEI were included in the study.

3.2 Customer Survey

Ewald and Wasserman recruited customers and administered a web survey with a sample of ESA participants and a comparison group of CARE/FERA[11] customers who have not participated in ESA since 2018. A total of 1,303 web surveys were completed (with 865 ESA participants and 438 comparison group respondents). Recruitment materials (emails and postcards) were sent in English or Spanish based on a preferred language variable in the IOU datasets.[12] The survey was conducted in both English or Spanish depending on respondent preference,[13] and participants were offered a $25 gift card to complete the survey.

The survey included the following components:

- Frequency of comfort, noise, air quality and chronic health condition symptom improvement benefits from ESA measures
- Identification of other factors responsible for these benefits
- Willingness-to-pay (WTP) for comfort, noise and air quality benefits[14]
- Conjoint / discrete choice questions that compare bundles of potential comfort, noise and air quality benefits

3.2.1 Customer Survey Sampling Approach

For ESA participants, the participant survey sample frame consisted of all households that participated in the ESA program in 2023 and Q1 2024. The participant group sample frame was stratified by measure group and IOU. For the comparison group, the study used stratified random sampling from each IOU to select comparison respondents covering the geographies represented by ESA participants to account for regional differences in weather and air quality.

Details regarding sampling and survey dispositions are provided in Appendix A.

[11] The California Alternate Rates for Energy (CARE) program and the Family Electric Rate Assistance (FERA) program provide a monthly discount on utility bills for lower income households. Customers who meet the CARE or FERA program income requirements are eligible for ESA participation.

[12] For records that identified a non-English and non-Spanish language preference, recruitment materials were provided in English.

[13] Respondents were able to select whether they took the survey in English or Spanish during the survey.

[14] The research team determined that willingness to pay to retain a benefit (as opposed to the amount a respondent would be willing to *accept* to lose a benefit) may be easier for respondents to answer than a traditional willingness to accept (WTA) style survey question. Thus, traditional WTA style survey questions were not included in the survey.

3.2.2 Survey Design

The customer survey included survey questions to understand how often comfort, noise and certain health-related benefits occur from ESA participation, customers' willingness-to-pay for comfort, noise and air quality benefits, and questions to support the conjoint analysis.

Given challenges identified by prior research trying to assess the value of HCS benefits, the research team took more extensive effort in developing and testing the survey questions, including:

- Review of past survey questions used to capture HCS benefits, leveraging the literature review conducted for this study
- Research team pre-testing of the survey instrument with 40 ESA program participants
- In-depth phone interviews with 27 customers who participated in the pre-test to talk through their responses and ensure that the intent of the questions was clear, and their responses reflected their opinions and experience
- Final round of revisions to the survey instrument to address the pre-test findings with Study Team input

The pre-test and follow-up interviews led to several important adjustments to the survey, including discarding the use of specific temperature differentials (i.e., 5°F too warm) when asking about the value of winter and summer comfort. The valuation questions were adjusted to align with the incidence and attribution questions that focused on "comfortable" versus "uncomfortable" (without specifying temperature differentials). Additional adjustments to the survey included applying randomization to the WTP question dollar amounts and clarifications to the conjoint survey instructions.

Throughout the survey instrument and testing process, the research team ensured that the average length of survey time did not exceed 20 minutes to ensure higher quality responses and increase the response rate. See Appendix D for the final survey instrument and Appendix E for the final recruitment materials.

3.3 Analysis

Evergreen analyzed participant and comparison group survey data to develop estimates of how often ESA treatments result in comfort, noise and health-related benefits, separating program impacts from factors like changing weather. The research team also developed regression models for willingness-to-pay and conjoint analyses to estimate monetary values for comfort, noise and air quality NEI metrics. By combining the frequency of benefits with their values and weighting based on typical measure combinations in ESA (in 2023 and Q1 2024), the research team estimated average comfort, noise and air quality benefit values for the program.

3.3.1 Contingent Valuation WTP Analysis

The customer survey included a traditional WTP set of survey questions for both participant and comparison group respondents that reported they had perceived an improvement in a comfort, noise or air quality metric. This method included a logistic regression model, a statistical method that predicts the probability of a binary outcome and was intended to complement the conjoint analysis. For this study the outcome is whether they are willing to pay the dollar amount proposed in the survey question for the described improvement in comfort, noise or air quality.[15]

3.3.2 Conjoint Analysis and MWTP

The survey also collected data to support a conjoint analysis. The conjoint analysis was based on survey responses to a series of questions that force the respondent to make choices between combinations of benefits. The conjoint design involved creating 12 unique scenarios that were shown in random pairs to both participant and comparison group survey respondents. This was done to understand how they value comfort, noise and air quality benefits. Each respondent was shown four pairs of scenarios. Table 1 provides an example of a conjoint choice presented to survey respondents.

Table 1: Conjoint Choice Example

	Scenario A	Scenario B
Monthly utility bill credit to you:	$10	$25
Indoor air quality	Good indoor air quality	Moderate indoor air quality
Indoor temperatures during the summer	Comfortable indoor temperature	Uncomfortably warm
Draftiness	Drafty	Little to no drafts
Noise in your home	Some noise	Very little noise
Please choose A or B	[ ]	[ ]

The two options (Scenario A and Scenario B) are not intended to be consistent with real-life combinations of options, by design. By mixing up the values in a non-intuitive way, the respondents are forced to decide what is more important between bill credits and the comfort-, air quality- and noise-related conditions.

[15] For the logistic regression the research team coded ‘Yes’ = 1 and ‘No’ = 0.

The data collected from the conjoint choice questions were used in a conjoint regression model, which analyzes how people weigh multiple factors when making choices. It reveals which features matter most and how much people value each characteristic when they must trade off different options—like choosing between more comfort versus lower cost. In this study, this method was used to determine the marginal willingness-to-pay (MWTP) of specific comfort, noise and air quality benefits, expressed as a dollar value.

3.3.3 Valuation Method Selection: Conjoint

Ultimately, the research team opted to use the MWTP values from the ESA participant conjoint analysis results for NEI valuation.

While WTP questionnaires effectively measure how people value non-market goods (e.g., open space or healthy communities), the research team questions whether they provide meaningful estimates of how low-income program participants, in particular, value NEIs. ESA participants are lower income and may be more likely to reject hypothetical payments (from them) for comfort in the survey, thus understating the value of NEIs due to their household budget constraints. The results of the WTP logistic regression analysis were WTP values considerably lower than those from the conjoint and included WTP values with very large standard errors compared to the more stable estimates from the conjoint analysis.

The research team believes the conjoint analysis may provide a better representation of the value individuals place on each of the comfort, noise and air quality NEIs as the comparison between alternative sets of attributes better replicates the actual process of making a purchase decision. The conjoint approach used by the study team also does not require low-income households to consider paying for a benefit, but rather revealing what characteristics are more and less important.

The research team also compared the conjoint analysis results from ESA participants and the comparison group households and noted that the MWTP was considerably lower from the survey of comparison homes than the participant homes. The research team concluded that since ESA Program participants opt into the program—which requires some level of their time and inconvenience (depending on the scale of their participation) in exchange for ESA Program benefits—they may value ESA Program benefits differently than non-participants (who comprise the comparison group households). Alternatively, ESA participants may better understand the value of the benefits after receiving the benefit. As a result, the research team determined that using the MWTP from the participant conjoint was most appropriate. More research would be needed to understand why ESA participants value the studied benefits more than similar non-participant households.[16]

Additional details regarding the study analysis approaches, as well as the WTP and conjoint analysis results and uncertainty metrics, are provided in Appendix B.

3.4 Study Limitations

While the study approach was designed to provide reliable estimates of comfort, noise and air quality benefits attributable to the ESA program, as well as whether symptoms of certain chronic health conditions improve from ESA treatments, several limitations should be considered when interpreting the results.

First, the study relies on self-reported data from ESA participants and a matched comparison group. Self-reported data is subject to recall bias, especially when respondents are asked to compare conditions before and after program participation. Additionally, respondents may have difficulty attributing specific changes in health, comfort, or noise directly to program measures versus other changes in their home environment. While the comparison group design helps mitigate some external factors (such as weather changes between years), it cannot completely isolate program effects from all potential confounding variables. Furthermore, the study relies on participant survey responses, which inherently reflect subjective opinions and may shift slightly if measured again—re-surveying the same individuals could yield different results due to evolving perceptions or changing circumstances.

The willingness-to-pay (WTP) method used in this study relies on stated preferences rather than actual market transactions, which may introduce hypothetical bias. Respondents may overstate or understate their valuation of benefits when not making actual financial commitments. Another challenge with WTP (and other contingent valuation approaches) is that respondents may provide responses with a strategic goal or constraint in mind. In particular, ESA participants are lower income by definition and may understate their true willingness-to-pay due to their household budget constraints. The conjoint analysis survey method serves to reduce these types of biases by allowing respondents to reveal their preferences by selecting one option or the other, without the ability to strategically bias the results.

The conjoint analysis methodology, while providing a useful framework for estimating tradeoffs between different attributes and indirectly estimating dollar values, also has its limitations. The attribute levels presented in the conjoint exercise necessarily constrained the range of possible conditions and monetary values, potentially not capturing the full spectrum of participant

[16] The study found that ESA participant survey respondents reported a higher incidence of chronic health issues. However, ESA participants did not value the studied NEIs statistically different (higher or lower) than households from the non-participant comparison group of survey respondents.

experiences. The statistical models used to analyze conjoint data assume that preferences for individual attributes can be aggregated to determine overall willingness-to-pay, but interactions between attributes (such as between noise levels and comfort) may be more complex than the model captures. Additionally, calculating marginal willingness-to-pay (MWTP) from conjoint-derived utility values requires assumptions about the linearity of monetary preferences, which may not perfectly reflect how households value incremental changes in their discretionary income at different income levels. The conjoint methodology may underestimate NEI values among low-income populations relative to moderate or high-income populations, as resource-constrained households may assign relatively higher marginal utility to monetary savings needed for essential expenses than to comfort improvements.

Sample sizes for certain subgroups or measure combinations were limited, potentially affecting the precision of benefit estimates for these specific segments. While the overall sample was designed to be representative of the ESA participant population, the ability to draw conclusions about certain demographic segments or rare measure combinations is constrained by smaller sample sizes within these categories. This limitation affects the ability to develop highly granularized benefit values for all possible program scenarios.

Finally, this study focused on a specific set of HCS-related impacts and was unable to address all potential benefits. Home safety improvements—such as reduced risk of fire hazards, carbon monoxide poisoning, or trip and fall incidents—were excluded due to the complexity of measuring the incidence (or lack of incidence) of these relatively rare events in a survey format. The study's health impact assessment was limited to indoor air quality and high-level symptom relief from chronic conditions and did not explore the full spectrum of potential health benefits, including changes in frequency or severity of colds, flus, and allergies. These additional topics were not addressable due to concerns over survey length (and respondent fatigue) as well as concerns about IOU customer privacy.

3.5 Considerations for Future Research

This study focused on NEIs addressable through survey research with low-income California households and did not cover all NEIs related to health and home safety from ESA participation. These excluded NEIs represent important areas for future research that could provide a more comprehensive understanding of the full benefits of the ESA Program. Subsequent research should consider methods beyond customer surveys due to the challenges addressing home safety and granular health impacts. This may include literature reviews and California-specific secondary data analysis to develop algorithms to quantify specific health and safety impacts.

The study also identified from the conjoint analysis that non-participant households valued comfort, noise and air quality considerably lower than the participant households. This finding was unexpected, and the cause of the difference is unknown—further research with participants may help understand why ESA Program participants appear to value comfort, noise and air quality more than non-participants.

4 Findings

This section presents the results of survey data analysis examining health, comfort, and noise non-energy impacts (NEIs) attributable to ESA program participation. Across all ESA participant survey respondents, 12 percent noticed one or more improvements in comfort, noise or air quality that they attributed in part to ESA participation.

In the analysis for comfort and air quality impacts in this section, the study distinguishes between "major" measures and "minor" measures based on expected outcomes to provide a more nuanced understanding of program impacts. For noise, the measures were split based on whether the impact may come from appliances (i.e., inside the home) or from reducing the amount of noise from the outside (i.e., from weatherization). See Table 11 in Appendix B for details regarding which measure types are associated with each measure group.

For each of the three types of comfort benefits examined—winter comfort, summer comfort, and reduced draftiness—and for improved indoor air quality and noise benefits, the study reports four sets of results:

1. **Identified Benefit:** The percentage of ESA participants who reported in the customer survey that they experienced the benefit after receiving relevant measures.
2. **Benefit from ESA:** How much of that improvement can be directly attributed to ESA measures rather than other factors based on analysis of the participant and comparison group responses to survey questions.
3. **Benefit Value:** The monetary value participants place on the benefit based on the conjoint analysis (expressed as $/year).
4. **ESA Provided Value:** The estimated value obtained by participants that receive the relevant measures through ESA, which is based on the combination of the prior three components, as shown in Equation 1.

Equation 1: ESA Provided Value Calculation

$$ESA\ Provided\ Value = Identified\ Benefit\ \times Benefit\ from\ ESA\ \times Benefit\ Value$$

Note that the ESA Provided Value is then applied proportional to the ESA measure mix across all participants to estimate the value provided on a per participant basis.

A summary of benefit values from the conjoint analysis is provided in Table 2. An in-depth explanation of how these benefit values were estimated is provided in Appendix B.

Table 2: Conjoint Analysis Benefit Values

Metric	Benefit Value ($/Year)
Winter / Summer Comfort	$242
Draftiness	$160
Indoor Air Quality	$129
Noise	$137

The research team investigated whether the incidence of benefits or the benefit values varied based on subgroup analysis (see Appendix C). There were no statistically significant differences in the incidences of improvements or the MWTP values based on the subgroup analyses.

The research team also analyzed survey responses related to whether ESA participation led to improvements in chronic health condition symptoms, though no valuation is provided.[17]

4.1 Participant Comfort

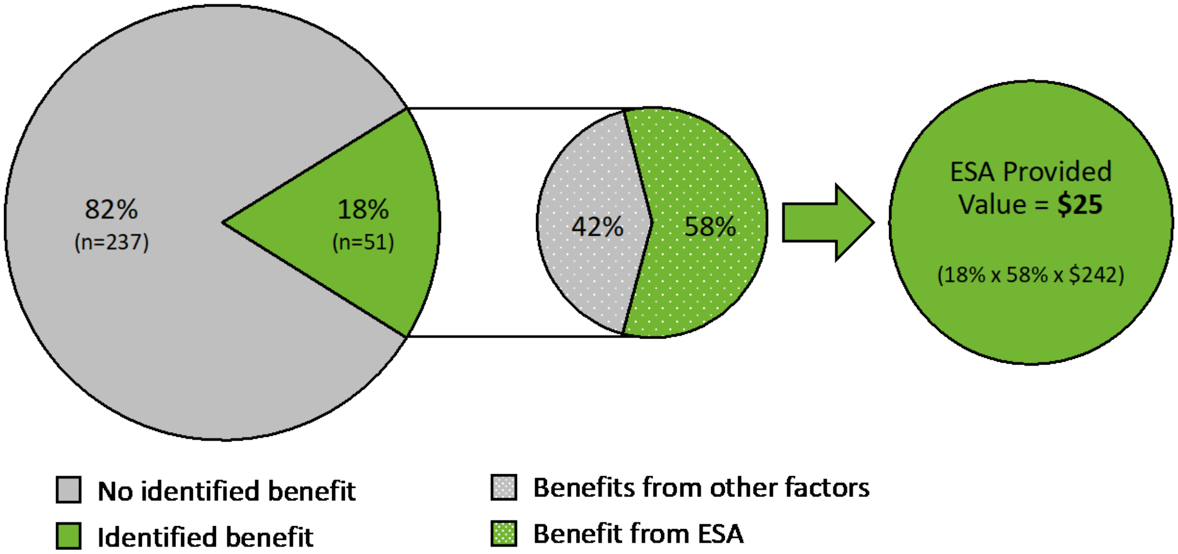
ESA Program participation can lead to improved winter and summer comfort, as well as reduced draftiness. This section provides findings related to the incidence of these comfort improvements occurring from participating in ESA, as well as their annual value per participant.

4.1.1 Increased Comfort in Winter

Based on responses to survey questions, 18 percent of ESA participants who responded to the survey that received major heating related measures identified an improvement in their winter comfort (see Figure 1). Of this, 58 percent of the benefit is estimated to be from ESA measures. The value of improved winter comfort is $242 per year, and thus the value of the additional winter comfort provided by ESA in 2023 was estimated to be worth $25 per year, per participant receiving at least one major heating-related measures.

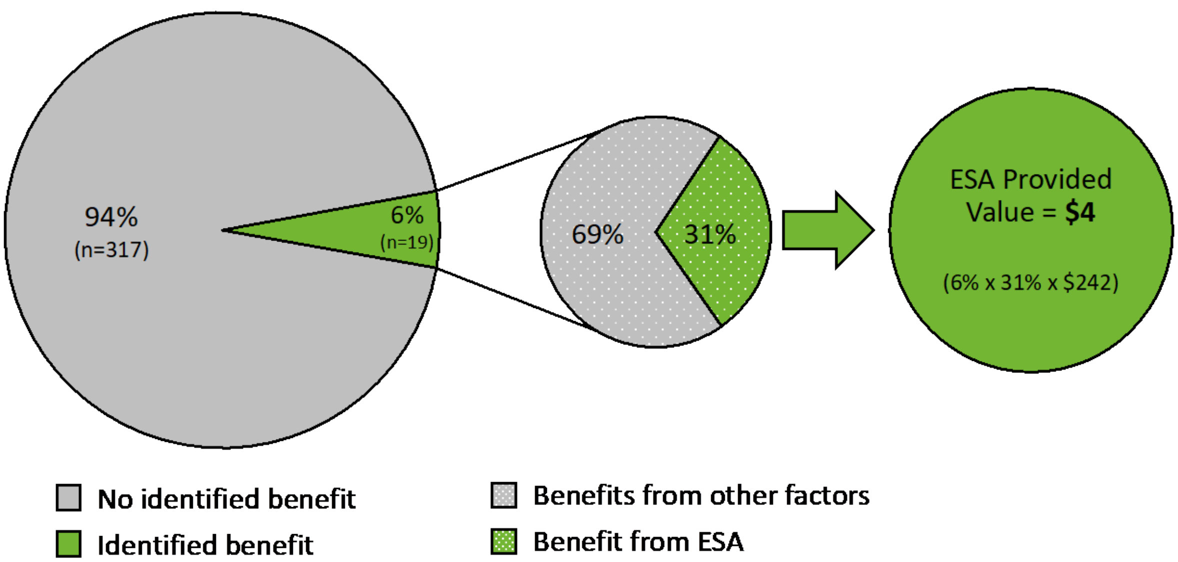
[17] The conditions included asthma, arthritis, COPD, and autoimmune diseases (e.g., Lupus, MS).

Figure 1: Winter Comfort from Major Heating-related Measures (n=288)



Survey data indicate that minor heating-related measures delivered through ESA resulted in winter comfort improvements for 6 percent of recipients (see Figure 2). These ESA interventions are estimated to account for 31 percent of the improvements. The ESA contribution was calculated at roughly $4 per year for each participant who received minor heating measures in 2023.

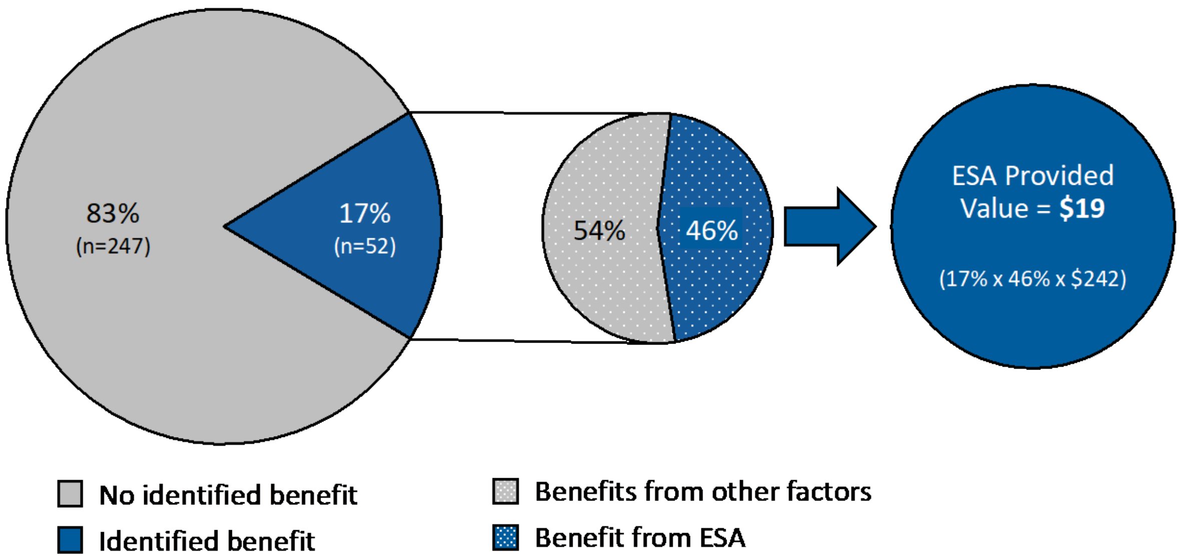
Figure 2: Winter Comfort from Minor Heating-related Measures (n=336)



4.1.2 Increased Comfort in Summer

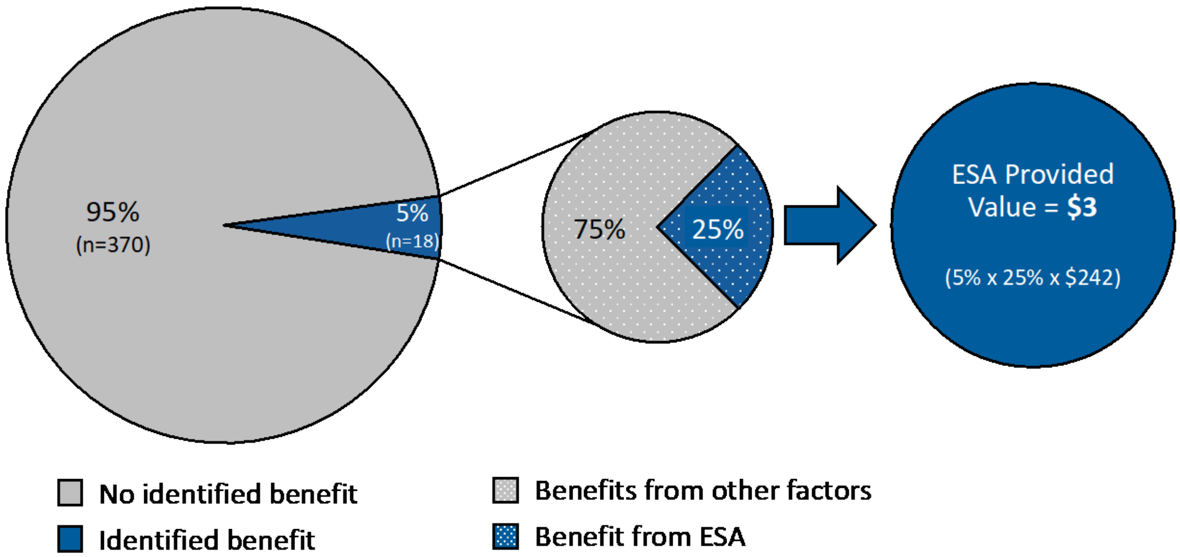
The study found that ESA program's major cooling-related measures yielded summer comfort improvements for 17 percent of participants according to survey responses (see Figure 3). Approximately 46 percent of this benefit is attributable directly to the measures implemented. With improved summer comfort valued at $242 per year, each participant who received major cooling measures in 2023 gained an estimated annual benefit of $19 from the program.

Figure 3: Summer Comfort from Major Cooling-related Measures (n=299)



Of participants receiving minor cooling-related interventions through ESA, 5 percent reported enhanced summer comfort (see Figure 4). The measures contributed an estimated 25 percent to these improvements. The annual value of summer comfort enhancements from ESA's minor cooling measures is approximately $3 per participant.

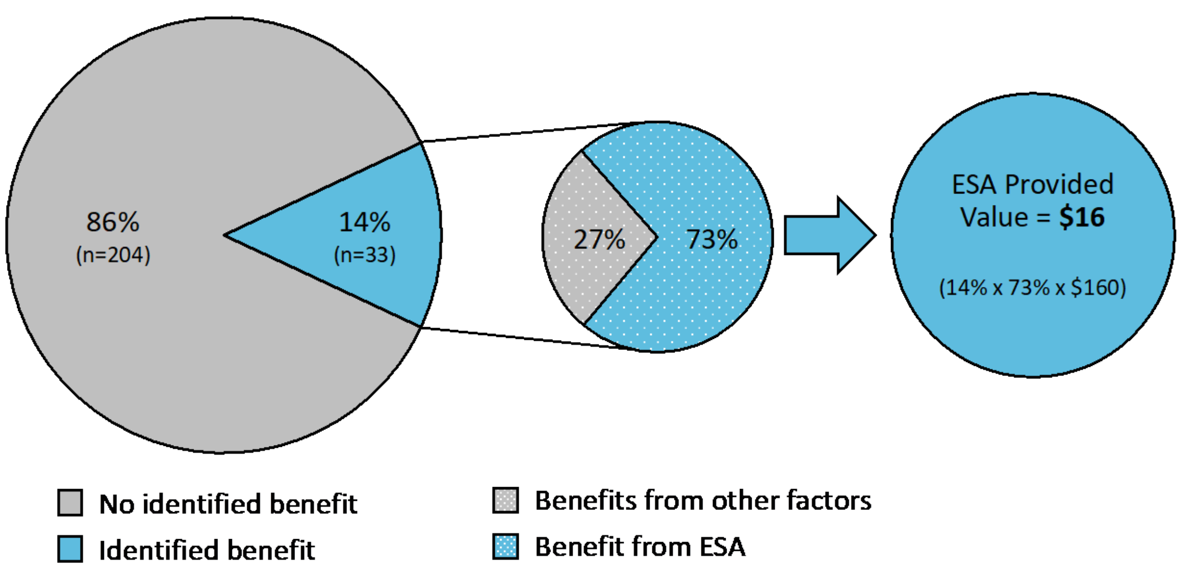
Figure 4: Summer Comfort from Minor Cooling-related Measures (n=388)



4.1.3 Reduced Draftiness

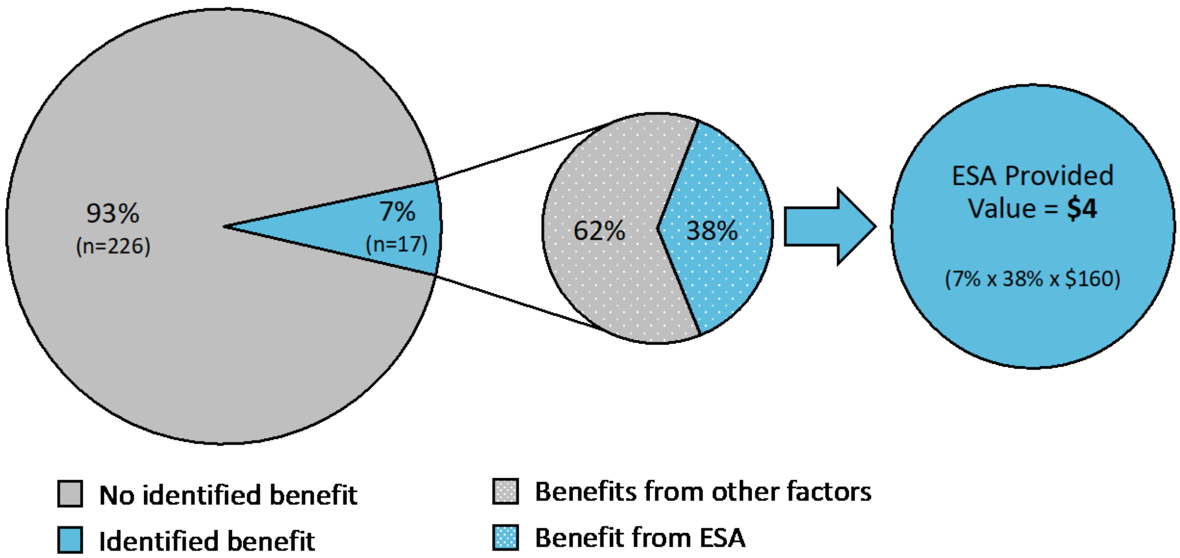
Survey results reveal that 14 percent of participants who received major draftiness-related measures experienced improvements in their home's air sealing (see Figure 5). These ESA interventions accounted for approximately 73 percent of the observed benefits. With draftiness improvements valued at $160 annually, the ESA contribution was calculated at $16 per year for each recipient of major draftiness measures.

Figure 5: Reduced Draftiness from Major Draftiness-related Measures (n=237)



Minor draftiness-related measures installed through ESA resulted in noticeable improvements for 7 percent of recipients according to survey data (see Figure 6). The ESA program is credited with 38 percent of these positive changes. As a result, participants who received minor draftiness measures in 2023 received approximately $4 in yearly NEI from the program.

Figure 6: Reduced Draftiness from Minor Draftiness-related Measures (n=243)



4.2 Reduced Noise in Homes

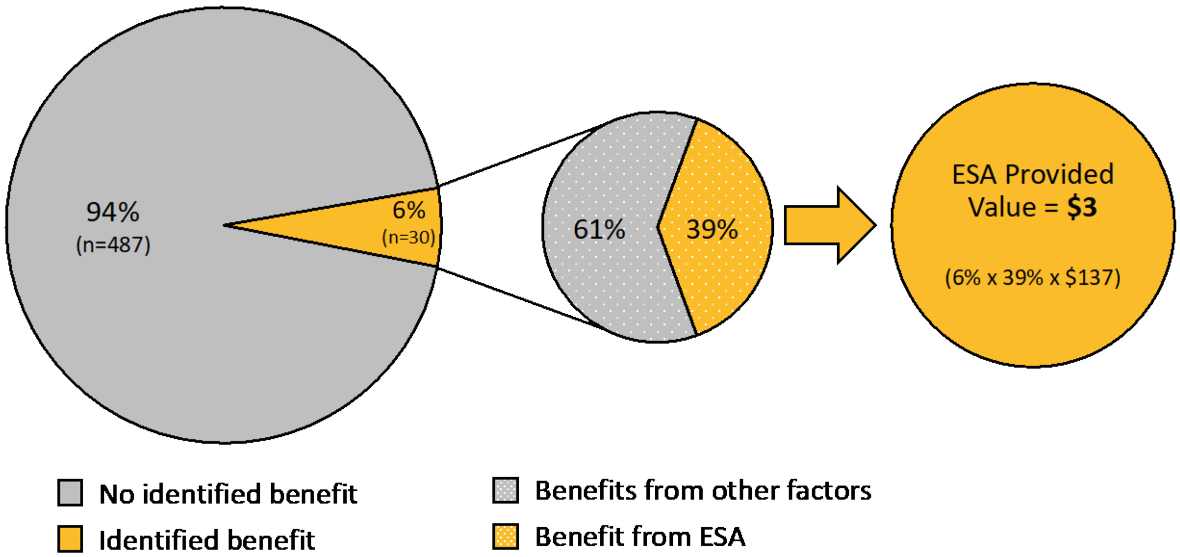
ESA Program participation can lead to reductions in indoor noise levels either from sources inside the home or from reducing how much outside noise is audible inside. This section provides findings related to the incidence of these noise-related improvements occurring from participating in ESA, as well as their annual value per participant.

4.2.1 Noise Reduction from Indoor Sources

Survey data indicates that 6 percent of participants who received new or repaired appliances or HVAC equipment experienced reduced interior noise (see Figure 7).[18] ESA measures accounted for approximately 39 percent of this improvement. The annual value of reduced noise is estimated at $137, meaning the ESA program delivered roughly $3 in yearly benefits to each participant receiving these equipment upgrades.

[18] This measure group includes participants that also received weatherization measures.

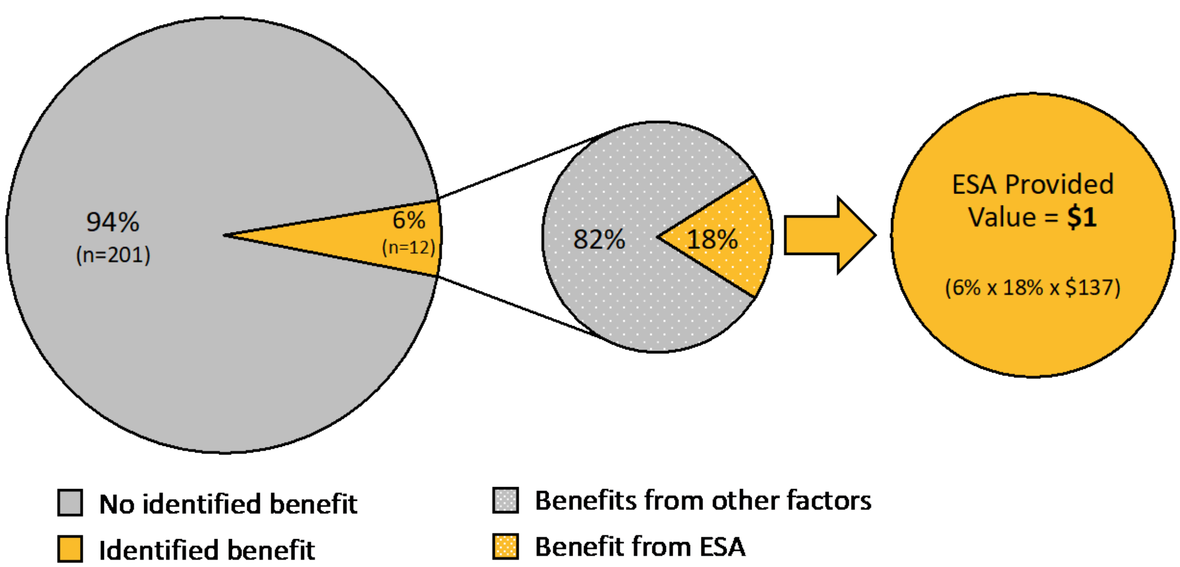
Figure 7: Reduced Noise from New or Repaired Appliances or HVAC Measures (n=517)



4.2.2 Noise Reduction from Outside Sources

Among participants that received relevant home improvement measures implemented through ESA (and did not also receive new or repaired appliances or HVAC equipment), 6 percent reported noise reductions (see Figure 8). These ESA interventions contributed an estimated 18 percent to the observed improvements. Participants who received these measures received approximately $1 in yearly benefits from the program, on average.

Figure 8: Reduced Noise from Weatherization Measures (n=213)



4.3 Participant Health

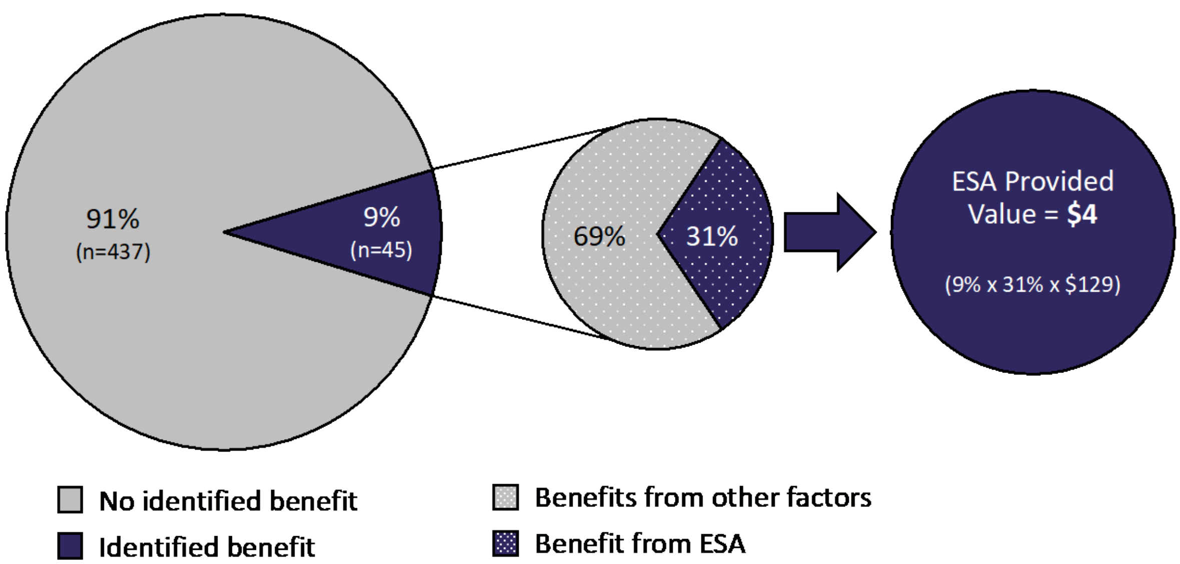
ESA Program participation may lead to improvements in indoor air quality that may impact the health of household occupants. This section provides findings related to the incidence of improved indoor air quality occurring from participating in ESA, as well as the annual value per participant. The section also provides an assessment of whether ESA participation leads to improvements in symptoms experienced by household members with chronic health conditions.

Note that there are other potential health benefits from ESA participation that were not included in this study.

4.3.1 Indoor Air Quality Improvements

Analysis of survey responses shows that 9 percent of participants who received major air quality-related measures reported improvements in indoor air quality (see Figure 9). ESA measures were reportedly responsible for 31 percent of this improvement. With better air quality valued at $129 annually, the ESA contribution in 2023 provided approximately $4 in yearly benefits per participant receiving these major air quality interventions.

Figure 9: Improved Indoor Air Quality from Major Air Quality-related Measures (n=482)



Recipients of minor air quality measures did not perceive statistically significant improvements in indoor air quality and thus there is no comfort benefit from these types of measures.

4.3.2 Symptom Improvement among Household Members with Chronic Health Conditions

The participant and comparison group survey captured how common certain chronic health conditions were in ESA participant and comparison group households. These conditions included asthma, arthritis, chronic obstructive pulmonary disease (or COPD), and autoimmune diseases. The survey also asked respondents whether symptoms related to these conditions had improved, worsened, or remained stable between 2023 and 2024, and whether ESA participants attributed their improved symptoms to relevant impacts from ESA measures, such as improved air quality or reduced draftiness (compared to factors unrelated to ESA like new medicines or a medical procedure).

Analysis of the survey data showed that ESA participant households more frequently included someone with a chronic health condition; however, no significant differences emerged in symptom improvement over time between ESA-treated homes and the comparison group:

- 45 percent of ESA participants (n=397 of 877) reported someone in their household had received a diagnosis of a chronic health condition, compared to 38 percent of comparison household respondents (n=168 of 446). This difference is statistically significant, but it is unclear why ESA participant households have higher rates of chronic health conditions than non-participants.
- Among households reporting the presence of a chronic health condition, 25% of both ESA participants (n=99) and comparison group respondents (n=42) reported an improvement in symptoms (either selecting that their symptoms improved or that some symptoms improved while others worsened).

The study investigated whether any major measures led to direct health impacts based on survey responses. Among ESA participant households with a chronic health condition that received a major cooling measure through ESA, two out of 167 households (1%) reported that their health condition(s) improved in part due to ESA measures. Households with health conditions that received major heating measures showed similar results (2 of 157, 1%), as did those receiving major air quality measures (2 out of 217, 1%).

In summary, ESA participants and comparison households reported similar rates of symptom improvement year-to-year, and very few symptom improvements among participant households were attributed to ESA measures. Most of the health symptom improvements resulted from other factors such as new medications, medical procedures, medical devices, or other symptom management approaches.

The research team also investigated whether households with chronic health conditions valued improved thermal comfort (winter/summer comfort), reductions in draftiness, and indoor air quality differently from households without chronic health conditions. Table 3 shows that there are no statistically significant differences in the valuations.

Table 3: Conjoint MWTP Subgroup Analysis Results (Participants) – Households with Chronic Health Conditions vs. Households without Chronic Health Conditions

Metric	Subgroup	MWTP (per month)	Standard Error	Lower Bound (95% C/I)	Upper Bound (95% C/I)
Winter / Summer Comfort	Health Condition(s)	$20	4.53	10.70	28.47
	No Health Condition	$22	4.75	12.46	31.09
Draftiness	Health Condition(s)	$13	2.95	6.93	18.51
	No Health Condition	$14	3.01	7.85	19.66
Indoor Air Quality	Health Condition(s)	$11	2.61	5.74	15.97
	No Health Condition	$11	2.43	5.91	15.45

Since the study did not encounter higher rates of symptom improvements in the treatment group than the comparison group, found that ESA measures were infrequently the cause of these improvements, and that homes with and without health conditions value potential ESA measure non-energy impacts similarly, the research team concludes that ESA does not have a meaningful impact on symptom improvement for the chronic health conditions included in this analysis.

It is possible that ESA measures may have other health-related benefits (i.e., reduction in the frequency/severity of colds, flus, and allergy symptoms) that were not covered in this study, which would be appropriate for further research.

4.4 Non-Energy Impacts of ESA Participation – Integration into Cost Effectiveness Accounting

To calculate the NEIs of ESA participation included in this study on a per participant basis requires applying the estimated ESA "Provided Value" of each NEI category for each measure group to the population of ESA participants. This produces the estimated NEI impacts of ESA (in 2023) across the entire participant population, with the comfort NEIs shown in Table 4 and the noise NEIs shown in Table 5.

Surveyed ESA Program participants that did not receive any of the types of equipment included in the measure groups below did not attribute any comfort, noise or air quality improvements to ESA treatments. This includes households that only received "Basic" treatments—these households did not attribute any improvements in comfort, air quality, or noise to ESA participation.

Table 4: ESA Attributable Comfort NEI Estimates Applied to Participant Population

Comfort Metric	Measure Group	Portion of Population of ESA Participants that received these measures* (A)	ESA Provided Value** (B)	Estimated NEI impact of ESA in 2023 (A) x (B)
Winter comfort	Major Heating	5%	$25	$1
	Minor Heating	47%	$4	$2
Summer comfort	Major Cooling	5%	$19	$1
	Minor Cooling	49%	$3	$1
Draftiness	Major Draftiness	17%	$16	$3
	Minor Draftiness	27%	$4	$1
Overall Comfort NEI				$9

* Source: IOU 2023 and Q1 2024 ESA Program measure installation tracking data; values do not add up to 100% as they reflect the portions of ESA participants that received measures associated with each measure group (some participants receive measures in multiple groups)
** Source: the benefit value multiplied by the fraction of ESA participants who experienced the benefit and where that benefit is attributable to the ESA program

Table 5: ESA Attributable Noise NEI Estimates Applied to Participant Population

Noise Metric	Portion of Population of ESA Participants that received these measures* (A)	ESA Provided Value** (B)	Estimated NEI impact of ESA in 2023 (A) x (B)
From Appliances	26%	$3	$1
From Outdoors	31%	$1	<$1
Overall			$1

* Source: IOU 2023 and Q1 2024 ESA Program measure installation tracking data; values do not add up to 100% as they reflect the portions of ESA participants that received measures associated with each measure group (some participants receive measures in multiple groups)
** Source: the benefit value multiplied by the fraction of ESA participants who experienced the benefit and where that benefit is attributable to the ESA program

Table 6 provides the estimated NEI impacts of ESA (in 2023) related to self-reported improvements in participant indoor air quality.

Table 6: ESA Attributable Indoor Air Quality (Health-related) NEI Estimates Applied to Participant Population

Measure Group	Portion of Population of ESA Participants that received these measures* (A)	ESA Provided Value** (B)	Estimated NEI impact of ESA in 2023 (A) x (B)
Major Air Quality	20%	$4	$1
Minor Air Quality	28%	-	-
Overall			$1

* Source: IOU 2023 and Q1 2024 ESA Program measure installation tracking data; values do not add up to 100% as they reflect the portions of ESA participants that received measures associated with each measure group (some participants receive measures in multiple groups)
** Source: the benefit value multiplied by the fraction of ESA participants who experienced the benefit and where that benefit is attributable to the ESA program

In order to apply the findings from this study to future ESA Program years, the research team recommends that the IOUs adopt the measure group-based NEI values provided in Table 4 for comfort and Table 5 for noise. These metric- and measure group-specific results can be adjusted to match future ESA Program accomplishments based on IOU-specific analysis during regular ESA annual reporting. The IOUs would tabulate the number of participants that comprise each measure group identified in the study and substitute these participant counts in place of the "Portion of Population of ESA Participants." To calculate the total comfort and noise NEIs requires multiplying the participant counts by the "ESA Provided Value" to derive the component NEI values for each IOU's ESA Program (i.e., for reduced draftiness). These component values are then added together to estimate the total comfort and total noise NEI from each ESA Program for each year.

The research team does not recommend replacing the current health NEI value used by the IOUs in the ESACET using the value for indoor air quality provided in Table 6. Additional research is needed to estimate a comprehensive health NEI from ESA Program participation.

5 Conclusions

1

The ESA Non-Energy Impacts Study found that there were quantifiable non-energy impacts for ESA participants who received certain types of ESA treatments

The study found that some ESA participants perceived comfort-, noise- and air quality-related improvements after receiving relevant measures from the ESA Program. While the percentage of ESA participants who perceived a comfort, noise or air quality improvement was low, a significant number of those who perceived an improvement attributed it to ESA.

Table 7 shows the proportions of ESA participant homes that received relevant treatments and perceived comfort, noise and air quality improvements, and an approximation of the percent of the improvement attributable to ESA.

Table 7: Frequency of Any Comfort, Noise or Air Quality Improvement at Participant Homes by Measure Group

Metric	Measure Group	Percent of ESA Participant Survey Respondents with Relevant Measures who Perceived Any Improvement	Percent of Improvement from ESA Participation**
Winter comfort	Major Heating	18%	58%
	Minor Heating	6%	31%
Summer comfort	Major Cooling	17%	46%
	Minor Cooling	5%	25%
Draftiness	Major Draftiness	14%	73%
	Minor Draftiness	7%	38%
Indoor air quality*	Major Air Quality	9%	31%
Noise	From Appliances	6%	39%
	From Outdoors	6%	18%

*There was no statistically significant improvement in indoor air quality among participants that received minor air quality measures.

**Weighted to the population of ESA-installed measures in 2023 within each measure group.

2

California low-income households value comfort, noise and indoor air quality benefits based on the conjoint analysis

The study also found that households valued comfort, noise and air quality benefits (regardless of receiving the benefit). Based on the results of the conjoint analysis, the study found that participants value comfort, noise and air quality benefits between approximately $129 per year (for indoor air quality) and approximately $242 per year for winter and summer comfort. Table 8 provides the estimated benefit values, which do not factor in how frequently these benefits occur from ESA Program participation.

Table 8: Estimated Value of HCS Benefits

Metric	Benefit Value ($/Year)
Winter / Summer Comfort	$242
Draftiness	$160
Indoor Air Quality	$129
Noise	$137

3

The comfort non-energy impact of ESA participation is $9 per ESA participant and the noise non-energy impact of ESA participation is $1 per ESA participant (on average per year) for 2023 participants.

Based on the proportions of ESA participants that reportedly perceived comfort and noise improvements attributable to ESA, and factoring in the frequency with which various measure groups were installed, the research team estimates that the average ESA participant received $9 in comfort NEIs and $1 in noise NEIs from participating in ESA in 2023 and Q1 2024.

In order to apply the findings from this study to future ESA Program years, the research team recommends that the IOUs adopt the measure group-based NEI values provided in Table 4 for comfort and Table 5 for noise.[19] The approach for calculating IOU-specific ESA Program comfort and noise NEIs is described in detail at the end of Section 4.4, which may be integrated directly into each IOU's ESA cost effectiveness tools.

[19] The research team does not recommend replacing the current health NEI value used by the IOUs in the ESACET using the value for indoor air quality estimated by this study as it is not a comprehensive health NEI valuation.

Appendix A: Sampling and Survey Dispositions

Based on discussions with the Study Team, the survey sampling plan covered a range of ESA measure types. This approach allowed the analysis results to be aggregated into representative ESA treatment packages for each IOU.

The study groups the ESA measure packages into five categories:

Measure Group 1 (Basic): Lighting, simple water measures

Measure Group 2 (Enclosure): Air sealing, insulation

Measure Group 3 (Non-Weather Sensitive Appliances): Water heater repair or replacement, refrigerators, other appliances

Measure Group 4 (Heating): Furnace repair or replacement, duct sealing, smart thermostats

Measure Group 5 (Cooling): Central AC, room AC, evaporative cooler, portable AC (replacement or installation of any) and AC tune-ups, duct sealing, smart thermostats

The survey dispositions and recruitment rates, by sampling measure group, are provided in Table 9.

Table 9: Overall Survey Dispositions and Recruitment Rates

Measure Group	Target (Initial)	Completes	% of Initial Target	Recruitment Outreach	Recruitment Rate
1 - Basic	120	120	100%	7,249	1.7%
2 - Enclosure	180	210	117%	6,826	3.1%
3 - Appliances	120	105	88%	5,233	2.0%
4 - Heating	300	234	78%	8,716	2.7%
5 - Cooling	220	196	89%	3,918	5.0%
Comparison	460	438	95%	15,085	2.9%
Total	**1,400**	**1,303**	**93%**	**47,027**	**2.8%**

After receiving the IOU ESA participant data, in several cases the sampling plan's initial targets by IOU and measure group were determined to be infeasible due to limited available sample. The Study Team directed us to adjust survey targets to prioritize robust samples by measure group rather than by IOU. Table 10 shows the adjustments to the original targets by IOU and measure group, as well as survey completes.

Table 10: Survey Target Adjustments by IOU and Measure Group

IOU	Measure Group	Target (Original)	Target (Revised)	Completes
PG&E	1 - Basic	30	30	30
	2 - Enclosure	60	87	87
	3 - Appliances	30	30	30
	4 - Heating	100	130	108
	5 - Cooling	60	20	14
	Comparison Group	120	120	120
SCE	1 - Basic	30	30	30
	2 - Enclosure	N/A	N/A	N/A
	3 - Appliances	30	30	30
	4 - Heating	N/A	N/A	N/A
	5 - Cooling	160	182	182
	Comparison Group	120	120	120
SDG&E	1 - Basic	30	30	30
	2 - Enclosure	60	54	53
	3 - Appliances	30	15	15
	4 - Heating	80	20	14
	5 - Cooling	N/A	N/A	N/A
	Comparison Group	100	100	100
SoCalGas*	1 - Basic	30	30	30
	2 - Enclosure	60	70	70
	3 - Appliances	30	30	30
	4 - Heating	120	152	112
	5 - Cooling	N/A	N/A	N/A
	Comparison Group	120	120	93
Total		**1,400**	**1,400**	**1,303**

*Note that the largescale urban wildfires that occurred in the Los Angeles area in Winter 2025 impacted our ability to reach heating and comparison group survey targets for SoCalGas.

Appendix B: Detailed Analysis Methods

For all analysis, the research team distinguishes between "major" measures and "minor" measures to provide a more nuanced understanding of program impacts. For noise, the measures were split based on whether the impact may come from appliances (i.e., inside the home) or from reducing the amount of noise from the outside (i.e., from weatherization). Table 11 provides the breakdown of how the measure groupings were paired to metrics for analysis.

Table 11: Metric to Measure Groupings for Analysis

Metric	Measure Group	ESA Measures Included in Measure Group
Comfort in Winter	Major	New heating equipment (including heat pumps), ceiling insulation
	Minor	Smart thermostats, heating equipment tune up/repairs, duct sealing, weatherization measures (caulking, sealing), windows and doors repair/replacement
Comfort in Summer	Major	New cooling equipment (including heat pumps and evaporative coolers), ceiling insulation
	Minor	Smart thermostats, cooling equipment tune up/repairs, duct sealing, weatherization measures (caulking, sealing), windows and doors repair/replacement
Draftiness	Major	Windows and door repair/replacement
	Minor	Weatherization measures (caulking, sealing), ceiling insulation
Indoor Air Quality	Major	Air purifiers, windows and doors repair/replacement, new heating equipment (including heat pumps), new cooling equipment (including heat pumps and evaporative coolers)*
	Minor	Heating equipment tune up/repairs, cooling equipment tune up/repairs, weatherization measures (caulking, sealing), ceiling insulation
Noise	From Appliances	New heating equipment (including heat pumps), new cooling equipment (including heat pumps and evaporative coolers), new water heaters, new refrigerators, new laundry equipment, new dishwashers, heating equipment tune up/repairs, cooling equipment tune up/repairs, water heater repairs Note that if a home *also* received measures to reduce noise from the outdoors, it was included in this group.
	From Outdoors	Weatherization measures (caulking, sealing), windows and doors repair/replacement, ceiling insulation

* HVAC equipment can impact air quality through improved filtration and/or mitigating dampness (i.e., dehumidification).

Incidence Analysis

The incidence analysis determined which ESA measure bundles produced statistically significant improvements in non-energy impacts (NEIs) compared to changes observed in the comparison group. This section describes the methodology used to calculate incidence rates.

Statistical Significance Testing

The research team first assessed which measure bundles resulted in statistically significant NEI improvements:

1. The research team compared improvement rates between:
    a. ESA participants who received a *Major* measure bundle versus comparison group respondents who did NOT self-install a *Major* bundle
    b. ESA participants who received a *Minor* measure bundle versus comparison group respondents who did NOT self-install ANY relevant measures
2. Statistical significance was evaluated at the 90% confidence level using two-proportion z-tests
3. When ESA participants experienced a higher incidence of improvement that was statistically significant, the research team concluded that the measure bundle had a verifiable impact on the NEI beyond exogenous changes observed in the comparison group
4. When differences were not statistically significant, the research team concluded that ESA could not claim that the measure bundle impacted the NEI, as improvements were no greater than those exhibited by the comparison group

Calculating Incidence Rates

For NEIs and measure bundles that showed statistically significant improvements:

1. The research team calculated the percentage of ESA participants who experienced improvements for each measure bundle
2. The research team focused on the participant group for these calculations because exogenous changes were measured and isolated in the subsequent attribution analysis
3. This approach allowed the research team to answer: "When ESA measures were installed, did the customer see an improvement?" The attribution step later addressed: "How much of the observed improvement was caused by ESA measures versus external factors?"

Variation Analysis by IOU and Climate

To identify potential differences in NEI incidence by utility provider and climate zone:

1. For each measure bundle, the research team calculated the percentage of ESA participants who experienced improvements by IOU

2. The research team compared each IOU's improvement rate to the combined rate across the other three IOUs (e.g., PG&E versus SCE, SDG&E, and SoCalGas combined)
3. When differences were statistically significant, the research team retained IOU-specific improvement rates for tailored NEI calculations
4. The research team repeated this process for climate zones, where relevant:
    a. High heating versus low heating zones for heating bundles
    b. High cooling versus low cooling zones for cooling bundles
    c. Low-low (low heating and low cooling) versus all other zones for draftiness bundles
5. Climate was assumed to be irrelevant for air quality and noise bundles

Limitations

Despite finding statistically significant differences in NEI incidence by IOU, sample sizes of customers who experienced improvements were relatively small. This limited the research team's ability to calculate customized attribution scores by IOU. The research team's estimates of NEI differences by IOU were therefore tailored using only two metrics:

1. Incidence rates (to account for differences in the likelihood of NEI improvements)
2. Population of measure bundles installed (to account for differences in each IOU's program priorities and offerings)

This approach allowed the research team to incorporate utility-specific variations while maintaining statistical reliability in our overall NEI calculations.

Table 12 shows the overall and utility-specific incidence rates, where they were statistically significantly different than the overall incidence. SoCalGas respondents reported significantly lower incidence rates of improvement in summer comfort from major cooling measures (9% among SoCalGas participants vs. 17% of all ESA participants) and lower improvements in draftiness from major draftiness measures (8% vs. 14%). SDG&E respondents reported significantly higher incidence of improvements in indoor air quality from major air quality measures (20% vs. 9%). SCE respondents reported higher incidence of improvements in winter comfort from major heating measures (26% vs. 18%), draftiness from minor draftiness measures (22% vs. 7%), and noise from outdoor noise measures (25% vs. 6%). When a utility's incidence was not statistically significantly different than the other utilities in other NEIs or measure bundles, the research team performed the NEI calculations using the average incidence across all utilities.

Table 12: IOU-Specific Incidence Rates

Metric	Measure Group	Incidence of Improvement Among Treated Homes (suppressing insignificant %s)				
		PG&E	SCE	SDG&E	SoCalGas	All IOUs
Comfort in Winter	Major	*	26%	*	*	18%
	Minor	*	*	*	*	6%
Comfort in Summer	Major	*	*	*	9%	17%
	Minor	*	*	*	*	5%
Draftiness	Major	*	*	*	8%	14%
	Minor	*	22%	*	*	7%
Indoor Air Quality	Major	*	*	20%	*	9%
	Minor	*	*	*	*	2%
Noise	From Appliances	*	*	*	*	6%
	From Outdoors	*	25%	*	*	6%

*These values were not statistically significantly different from the incidence of improvement for "All IOUs".

Table 13 shows the proportion of all ESA participants that received each measure bundle, by utility. SDG&E and SoCalGas installed more major heating equipment measures (13% and 15%) than PG&E or SCE (4% and 1%). When these are used to estimate the overall NEI across all measure bundles, major heating measures will be more influential for SDG&E and SoCalGas.

Table 13: Proportion of ESA Participants by Measure Bundle and IOU

Metric	Measure Group	PG&E	SCE	SDG&E	SoCalGas	All IOUs
Comfort in Winter	Major	4%	1%	15%	13%	5%
	Minor	88%	17%	76%	69%	47%
Comfort in Summer	Major	2%	22%	3%	10%	5%
	Minor	91%	21%	85%	71%	49%
Draftiness	Major	36%	<1%	0%	21%	17%
	Minor	51%	<1%	88%	39%	27%
Indoor Air Quality	Major	38%	22%	13%	24%	20%
Noise	From Appliances	27%	94%	34%	43%	26%
	From Outdoors	68%	<1%	66%	34%	31%

Attribution Analysis

When a respondent said they saw an improvement in a metric, they were asked to identify which factors were relevant to that improvement and then rank them. The attribution analysis quantifies the extent to which the observed improvements are attributable to specific ESA program measures, relative to any external factors that also caused improvements. The attribution analysis was comprised primarily of a causal inference and factor attribution analysis, with further insights provided by a comparative analysis and a subgroup (i.e., demographic) analysis.

Note: The research team only asked about reasons why NEIs improved, not why some got worse. If there are any comfort- or noise-related consequences from installing the measures, the study does not address those factors.

Data Cleaning and Post-Coding

Before beginning the attribution analysis, the research team conducted thorough data cleaning to ensure accuracy:

1. The research team reviewed free-response "other" attributions and reassigned them to existing survey options when appropriate (e.g., if a respondent wrote in "new AC" when there was already a survey option for this).
2. The research team identified patterns in responses that suggested new attribution factors. For example, after noting that some respondents attributed improvement in noise to new refrigerators, the research team post-coded a new attribution factor for this NEI.

Correcting for Non-Applicable Measures

A significant methodological challenge was that respondents could assign a zero score to measures they had not received, which could artificially reduce attribution scores for those measures. For instance, an ESA participant may have received only weatherization from ESA, but they also self-installed a new furnace (or their landlord installed a new furnace). As shown in Table 14, 12 percent of ESA treated customers and 9 percent of the comparison group installed new furnaces or other heating equipment. These measures may be less energy efficient than what ESA is installing, but they will still have the potential to cause NEIs.

Table 14: Self-Installed Measures

Self-Installed Measures	Treatment (n=877)	Comparison (n=446)
New windows	12%	7%
New exterior doors	7%	5%
New furnace or other heating equipment	12%	9%
New air conditioner or other cooling equipment	14%	12%
Added insulation	9%	6%
Increased the size of the home	2%	1%
Other	7%	3%

When a participant received measures from ESA and self-installed other equipment during the same year, the improvement in winter comfort that they reported (which is reflected in the incidence score) could be caused by a combination of the ESA measures and these self-installed measures, in addition to other exogenous factors (e.g., a warmer winter). While this does not impact the factor-level scores for an individual respondent, it does impact the overall average for the factor [e.g., average(NA, 1, 3)= 2, whereas average(0, 1, 3)=1.33]. To address this:

1. The research team created a comprehensive "detailed measure bundle" for each respondent by combining:
    a. ESA installation data
    b. Self-reported installations from Q7 in the participant survey
    c. Free-responses to Q7 (other) indicating installed equipment
2. For any measure-related attribution factor scored as zero, the research team then:
    a. Verified if the respondent had received or installed that measure
    b. Retained the zero if they had the measure
    c. Recoded to "NA" if they did not have the measure

3. For certain factors without verifiable installation data (home remodels, portable space heaters, refrigerators, and new ceiling or room fans), the research team:
    a. Cross-referenced attributions across different NEIs - if a respondent ever attributed an improvement to a specific measure in any NEI section, the research team confirmed they had that measure and retained zeros for that measure in other NEI attributions.
    b. If the factor was never attributed with an improvement, the research team had no other way to verify whether the factor was relevant. In these cases, the research team calculated the attribution scores two ways:
        i. Retaining these '0' scores
        ii. Setting unverifiable '0s' to 'NA'.

    The research team expects that some (but not all) of these unverifiable 0's are true 0's. By doing the calculations two ways (1. Assuming any unverifiable 0s are true 0s, and then 2. Assuming any unverifiable 0s are NA), and then taking the average of the two scores, the analysis essentially assumes that 50 percent are true 0s.

Weighted Attribution Scores

To account for variations in measure installation rates and generate more representative attribution scores:

1. The research team calculated a weighted attribution score for each major and minor measure bundle using:
    a. The attribution score for each survey factor
2. The installation rate of that factor among all ESA participants with this bundle
3. This weighted approach produced adjusted attribution scores that reflect how common each measure is within the bundle (e.g., furnaces have a higher attribution for winter comfort improvements than insulation, but they are also less common). This methodology allowed the research team to determine the relative importance of program measures versus external factors in producing the observed comfort, noise and air quality benefits, while accounting for the varying prevalence of different measures in the ESA program.

The objective of this analysis was to estimate the proportion of improvement in winter comfort that is attributable to ESA interventions, as opposed to exogenous changes. Table 15 provides an example of the attribution scores and weighting process for winter comfort. Survey respondents identified 15 factors that led to their improvement in winter comfort in 2024, these are listed in descending order of their relative attribution to winter comfort. Around half (6 of 15) of these factors were exogenous changes that have nothing to do with ESA (e.g., portable space heaters, warmer winter).

Among customers who experienced an improvement in winter comfort that had installed new heating equipment, 39 percent of their improvement was attributed to the new equipment. Within the population of homes treated by ESA in 2023 and Q1 2024 that received a major heating measure, 36 percent installed new heating equipment.

The overall attribution score for the ESA measure bundles (the bottom row) is a composite of each applicable measure (e.g., new heating equipment and new insulation), weighted by the proportion of ESA participants who received each measure. The percentage of measures installed do not add to 100 percent because most participants received multiple measures (e.g., heating equipment tune-ups and weather sealing), which can influence winter comfort. New heating equipment was most often attributed with the improvement in winter comfort, but it was installed much less often than new insulation (36% vs. 67% installed these measures within the major heating bundle). For this reason, new insulation contributes more to the overall ESA attribution score for the major heating bundle than the new heating equipment. Overall, the major heating bundle was credited with 58 percent of the improvement in winter comfort while the minor heating bundle was credited with 31 percent.

Table 15: Winter Comfort Attribution by Factor and Bundle

Factor relevant to the improvement in winter comfort	Attribution Score (B)	Presence of Measure within Major Heating Group (D)	Contribution to Total Score (B x D)
New heating equipment was installed	39%	36%	14%
Heating equipment was cleaned, fixed, or tuned up	31%	21%	7%
New portable space heaters	24%		
New windows and/or exterior doors	23%	25%	6%
We use a smart thermostat now	22%	28%	6%
Home was remodeled	22%		
New insulation added	25%	67%	17%
Heating ducts were fixed	14%	44%	6%
It's been warmer this winter	12%		
We've had more or less rain	5%		
New window caulking and sealing	5%	59%	3%
We can afford to heat the home more	4%		
It's been more or less humid	3%		
Other	3%		

Occupants of the home changed	1%		
Overall ESA Attribution Score			**58%**

Note: Both ESA participants and comparison customers were used in the attribution analysis. The purpose of the comparison group in this exercise was to bolster our measurement of exogenous factors. Just like the ESA participants, many of the comparison customers self-installed equipment. The research team went through the same data cleaning and calculation procedure to distinguish between true '0s' as opposed to 'NA' factors. The research team conducted a test, comparing the incidence of NEI improvements for ESA installed equipment to self-installed equipment. From this analysis, the research team concluded that there was no statistically significant difference. In other words, a new furnace was similarly likely to lead to an improvement in winter comfort if it was installed by ESA, self-installed by an ESA participant, or self-installed by someone in the comparison group. Because there were no statistically significant differences and our sample size in the attribution exercise was limited, the research team utilized the attribution scores assigned to both ESA and self-installed equipment to create our overall attribution scores for each piece of equipment. The weights applied in this step also help to correct for any imbalance in the attribution scores that could have resulted from the inclusion of self-installed equipment, adjusting the overall score to represent the true mix of ESA measures installed by the program in treated homes.

Willingness to Pay (WTP) Contingent Valuation

To estimate WTP from contingent valuation questions, the research team used binary logistic regression models. The initial modelling approach included several variables, but they were dropped as they did not add significance to the model. These included climate zone groups, presence of elderly, presence of children, total occupancy, high HDD zones, high CDD zones, by IOU, for PG&E versus all other IOUs, presence of cooling. The final models focused on bid amount, only, which showed the highest levels of statistical significance.

The dependent variable was binary, indicating whether the respondent was willing to pay a given bid amount (1 = Yes, 0 = No). The primary independent variable was the bid amount, which was randomly assigned and varied by question type:

- For draftiness, air quality, and noise, respondents first saw a bid of $5, followed either by a lower bid (of $2 or $3) or a higher bid of ($10 or $12).
- For temperature-related comfort, respondents were first shown a bid of $10, followed either by a lower bid ($2 or $5) or a higher bid ($20, $25, or $30).

Initially, models were estimated separately by category and WTP type (“obtain” vs. “retain”) to investigate whether obtaining a benefit was more or less valuable than retaining a benefit. In the end, the differences were minimal and the WTP types were combined.

The model was specified as follows:

$$Logit\big(P(Yes)\big) = \beta_0 + \beta_1(Bid\ Amount) + \epsilon$$

Where:

P(Yes) is the probability that the respondent is willing to pay the specified amount
β_0, β_1 are the estimated coefficients
ϵ is the error term.

Estimated coefficients were used to calculate WTP using the delta method, which transforms the log-odds scale into a dollar value using the formula:

$$WTP = \frac{\ln(1 + exp^{\beta_0})}{\beta_1}$$

Where:

WTP is the dollar value the customers are willing to pay
β_0, β_1 are the estimated coefficients

This approach provides a dollar-based estimate of the value respondents place on retaining or obtaining improved comfort or reduced noise. The WTP analysis results are provided for completeness in Table 16. These results were not used in the analysis of NEIs (see Section 3.3.3 for details regarding methods selection).

Table 16: WTP Analysis Results

Metric	WTP Estimate (per month) (A)	Standard Error	Lower Bound (95% C/I)	Upper Bound (95% C/I)	# of Months (from survey) (B)	NEI Estimate (annual)* (A) x (B)
Winter comfort	$21	10.79	0.27	42.58	3	$64
Summer comfort	$13	4.14	5.34	21.55	3	$40
Draftiness	$0	76.68	-184.84	115.73	12	$0
Indoor Air Quality	$1	0.14	0.50	1.04	12	$9
Noise	<$1	0.10	0.29	0.68	12	$6

*These values are comparable to the “Benefit Values” from the Conjoint analysis and have not been adjusted based on incidence or attribution among participants.

Conjoint Analysis and MWTP

The objective of the conjoint analysis is to estimate the marginal willingness to pay (MWTP) of various home comfort attributes (air quality, summer comfort, draftiness, noise) through respondents' preferences when making trade-offs between these attributes and monetary payments. The research team estimated MWTP as the term "marginal" refers to the estimates as being relative to a baseline. For example, with respect to air quality, the MWTP represents our estimate of how much a respondent would be willing to pay on average for good indoor air quality, relative to moderate indoor air quality.

Survey respondents from both the participants and comparison groups completed a choice-based conjoint exercise where they selected their preferred option between two hypothetical home comfort scenarios. Each scenario varied in:

- **Monthly Payment Amount**: $1, $10, $25
- **Indoor Air Quality**: Good Indoor Air Quality, Moderate Indoor Air Quality
- **Summer/Winter Comfort:**[20] Comfortable, Uncomfortably Warm/Cool
- **Draftiness:** Little to No Drafts, Drafty
- **Noise:** Very Little Noise, Some Noise

Conjoint Scenarios (Cards)

The scenarios were created using a fractional factorial design and are shown in Table 17. Respondents were presented with either indoor temperatures during the winter or summer, but not both.

[20] Respondents received either winter or summer in their conjoint card choices.

Table 17: Conjoint Options (Cards) Presented to Respondents

Card	Credit on your monthly utility bill	Indoor air quality	Indoor temperatures during the [SEASON]	Draftiness	Noise in your home
A	$1	Good indoor air quality	Comfortable	Drafty	Some noise
B	$25	Good indoor air quality	Comfortable	Drafty	Some noise
C	$10	Moderate indoor air quality	Uncomfortably [TEMP]	Drafty	Some noise
D	$1	Moderate indoor air quality	Comfortable	Little to no drafts	Some noise
E	$10	Good indoor air quality	Uncomfortably [TEMP]	Little to no drafts	Some noise
F	$25	Moderate indoor air quality	Uncomfortably [TEMP]	Little to no drafts	Some noise
G	$10	Moderate indoor air quality	Comfortable	Drafty	Very little noise
H	$1	Good indoor air quality	Uncomfortably [TEMP]	Drafty	Very little noise
I	$25	Moderate indoor air quality	Uncomfortably [TEMP]	Drafty	Very little noise
J	$10	Good indoor air quality	Comfortable	Little to no drafts	Very little noise
K	$25	Good indoor air quality	Comfortable	Little to no drafts	Very little noise
L	$1	Moderate indoor air quality	Uncomfortably [TEMP]	Little to no drafts	Very little noise

Model Specification

The research team estimated a binary logistic regression model for each group (treatment and comparison) where the dependent variable indicated which scenario was chosen. The model included the monthly payment amount (credit) and the comfort attributes as predictors:

$$
\begin{aligned}
Logit\big(P(Yes)\big) \\
&= \beta_0 + \beta_1(Payment\ Amount) + \beta_2(Air\ Quality) \\
&\quad + \beta_3(Temperature\ Comfort) + \beta_4(Draftiness) + \beta_5(Noise) + \ \epsilon_1
\end{aligned}
$$

Where:

β_1 to β_5 are the estimated part-worth coefficients (reflecting the preference weight) for each attribute.

ϵ_i is the error term capturing random variations.

Monetary Valuation of Attributes

To translate the estimated coefficients into monetary values, the research team used the delta method to calculate marginal willingness to pay (MWTP) for each comfort attribute. The MWTP formula is:

$$MWTP = \frac{\ln(1 + exp^{\beta_0+\beta_k})}{\beta_1}$$

Where:

MWTP is the marginal dollar value the customers are willing to pay
β_0, β_1, β_k are the estimated coefficients

This approach transforms model coefficients from log-odds into interpretable dollar values that represent how much respondents are willing to pay for improvements in each attribute.

The result of the conjoint analysis for the participant homes is provided in Table 18. These values are used as the “Benefit Value” in Section 4 of this report.

Table 18: Conjoint MWTP Analysis Results (Participants)

Metric	MWTP Estimate (per month) (A)	Standard Error	Lower Bound (95% C/I)	Upper Bound (95% C/I)	NEI Estimate (annual)* (A) x (12 mos)
Winter / Summer Comfort	$20	3.05	14.16	26.13	$242
Draftiness	$13	2.03	9.39	17.34	$160
Indoor Air Quality	$11	1.69	7.43	14.06	$129
Noise	$11	1.76	8.01	14.90	$137

The result of the conjoint analysis for the comparison homes is provided in Table 19. These values are provided for completeness but were not used in the analysis. The MWTP is considerably lower from the survey of comparison homes than the participant homes. The research team concluded that since ESA Program participants opt into the program—which requires some level of their time and inconvenience (depending on the scale of their participation) in exchange for ESA Program benefits—they may value ESA Program benefits differently than non-participants (who comprise the comparison group households). As a result, the research team determined that using the MWTP from the participant conjoint (in Table 18) was most appropriate.

Table 19: Conjoint MWTP Analysis Results (Comparison)

Metric	MWTP Estimate (per month) (A)	Standard Error	Lower Bound (95% C/I)	Upper Bound (95% C/I)	NEI Estimate (annual)* (A) x (12 mos)
Winter / Summer Comfort	$12	1.83	7.91	15.10	$138
Draftiness	$7	1.17	4.98	9.56	$87
Indoor Air Quality	$6	1.07	4.20	8.39	$76
Noise	$6	0.99	4.06	7.94	$72

Separate Seasonal Models vs Thermal Comfort Model

The research team also estimated models separately by season (winter vs. summer) based on whether survey respondents were trading off winter comfort or summer comfort (respondents received one of the other in their conjoint card choices). The findings for the separated models were consistent with the combined thermal comfort models and the research team selected to use the combined thermal comfort models as a result.

Addressing Irrational Choice Behavior

During the analysis, the research team identified two scenarios where respondent behavior deviated from what economic theory would consider rational. First, in some choice sets that included Card K—a scenario that offered the highest monetary credit and the most favorable levels across all comfort attributes—some respondents chose the alternative card. Second, in scenarios where Cards A and B were paired and identical in every attribute except that Card B offered a higher credit amount, some respondents still selected Card A.

These choices are inconsistent with rational utility maximization and likely reflect misunderstanding, inattention, or survey fatigue (a possible limitation of the study approach).

To assess the impact of these anomalies on model performance, the research team implemented a sensitivity adjustment where the research team recoded the binary choice variable to enforce rational selections: when Card K was present, it was assigned as the chosen option; when both A and B were shown, Card B was designated as selected. This correction was necessary because the presence of irrational responses made it difficult for the model to detect statistically significant patterns in preferences. By adjusting these specific cases to align with economically rational behavior, the research team was able to recover stronger and more interpretable model estimates that more accurately reflect the underlying trade-offs respondents made.

Appendix C: Subgroup Analysis

To better understand if ESA led to improvements in comfort, noise or air quality reductions among certain subgroups of the overall population, Evergreen investigated the following topics:

- Differences in the incidence of improved summer comfort among participants that received major and minor cooling-related measures by areas with high cooling needs (based on CDD) vs areas with low cooling needs.
- Differences in the incidence of improved winter comfort among participants that received major and minor heating-related measures by areas with high heating needs (based on HDD) vs areas with low heating needs.
- Differences in the incidence of improved indoor air quality among participants that received major and minor air quality-related measures, using PG&E as a proxy for Northern California compared to Southern California (comprised of all other IOUs).
- Differences in the incidence of draftiness among participants that received major and minor draftiness measures between the mild climates (low heating and low cooling) and other climates (high heating and/or high cooling).

Additionally, the research team investigated whether there are differences in the MWTP for comfort, noise and air quality benefits based on Conjoint analysis across the following subgroups:

- By IOU
- Households with elderly members compared to households without elderly members

There were no statistically significant differences in the incidences of improvements or the MWTP values based on the subgroup analyses.

Incidence of Improvement Subgroup Analysis

The study found no statistically significant differences in incidence of improvements based on this subgroup analysis. The results are provided in the tables below for completeness.

Table 20: Incidence of Improved Summer Comfort (Participants) – by Climate Zone (for CDD)

Measure Group	Climate Zone (Cooling Needs)	Incidence of Improvement
Major Cooling	High CDD	12%
	Low CDD	14%
Minor Cooling	High CDD	3%
	Low CDD	4%

Table 21: Incidence of Improved Winter Comfort (Participants) – by Climate Zone (for HDD)

Measure Group	Climate Zone (Heating Needs)	Combined Incidence and Attribution
Major Heating	High HDD	12%
	Low HDD	13%
Minor Heating	High HDD	5%
	Low HDD	1%*

*Not statistically different from 0%

Table 22: Incidence of Improved Air Quality (Participants) – PG&E vs. Other IOUs

Measure Group	Climate Zone (Heating Needs)	Combined Incidence and Attribution
Major Air Quality	PG&E Participants	6%
	Other IOU Participants	9%
Minor Air Quality	PG&E Participants	2%*
	Other IOU Participants	1%*

*Not statistically different from 0%

Table 23: Incidence of Improved Draftiness (Participants) – High HDD or CDD vs. Low HDD and CDD

Measure Group	Climate Zone (Heating Needs)	Combined Incidence and Attribution
Major Draftiness	High HDD or CDD	11%
	Low HDD and CDD	15%
Minor Draftiness	High HDD or CDD	4%
	Low HDD and CDD	5%*

*Not statistically different from 0%

Conjoint Analysis for Subgroups

The study found no statistically significant differences in MWTP from the conjoint analysis when conducting separate conjoint analyses based on subgroups. The results are provided in the figures below for completeness. The bars represent the approximate MWTP from the conjoint subgroup analysis with the lines representing the 95% confidence intervals.

Figure 10: Conjoint MWTP by IOU and Overall

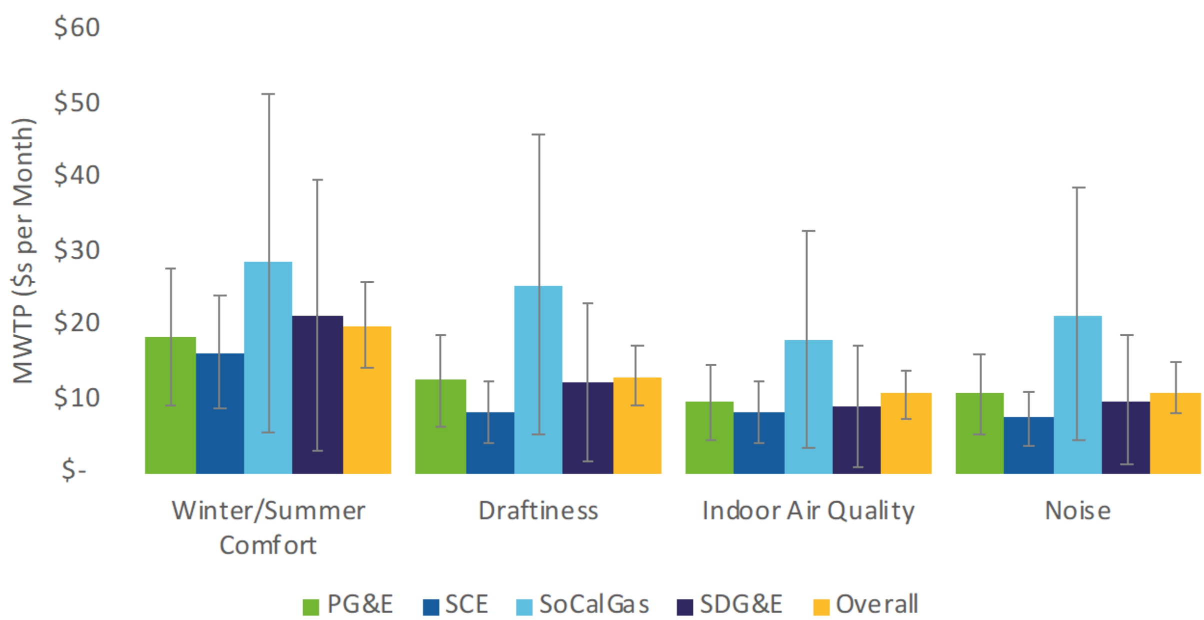
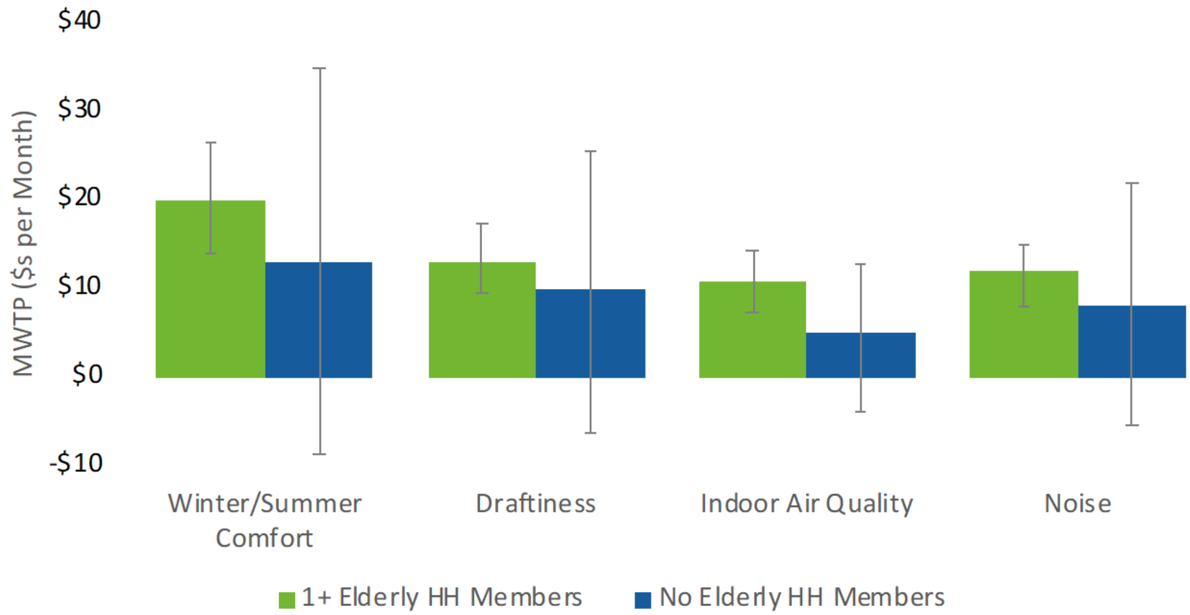


Figure 11: Conjoint MWTP by Presence of 1+ Elderly Members in Household



Appendix D: Survey Guide

Survey Intro

On behalf of the California Public Utilities Commission (CPUC) and [IOU NAME], thank you for responding to this survey!

To receive the $25 e-gift card, **you will need to complete the online survey** and provide the email address for the gift card.

Your responses will be confidential, and responses will be combined when reported. No individual responses will be shared.

Before we continue, can you please confirm that you have lived in the same house since the start of 2023 (or before)?

Yes
No

[If Yes, continue]

[If No:] "We can only complete this survey with people who have lived in the same house since the start of 2023. We appreciate your willingness to participate, but unfortunately you are not eligible to complete the survey." [TERMINATE]

[Show if they confirm]

Email address (where you would like your $25 e-gift card sent once you complete the survey): <OPEN>

*[**FOR PG&E ONLY**]* https://www.pge.com/en/privacy-center/privacy-policy.html

*[**FOR SDG&E ONLY**] During this survey we may collect personal information. For more details including SDG&E's policy on how they use personal information please visit* https://www.sdge.com/privacy

*[**FOR SCE ONLY**] During this survey we may collect personal information. For more details including SCE's policy on how they use personal information please visit* https://www.sce.com/privacy

*[**FOR SoCalGas ONLY**] Please note that personal information will be collected and used for the ESA Program. For more information on privacy policies and California Consumer Privacy Act (CCPA) compliance, please visit* www.socalgas.com/privacy-center

By clicking "Begin the survey" you agree to participate in the online survey.

Background Questions

The first questions are about your household and home.

Q1. How many people, including yourself, live in your home? [FORCE RESPONSE]
  a. 1, I live alone
  b. 2
  c. 3
  d. 4
  e. 5
  f. 6 or more
  g. Don't know / Prefer not to say

Q2. How many people over 65 years old live in your home? [FORCE RESPONSE]
  a. 0
  b. 1
  c. 2
  d. 3
  e. 4
  f. 5
  g. 6 or more
  h. Don't know / Prefer not to say

Q3. How many people under 18 years old live in your home? [FORCE RESPONSE]
  a. 0
  b. 1
  c. 2
  d. 3
  e. 4
  f. 5
  g. 6 or more
  h. Don't know / Prefer not to say

Q4. Compared to a year ago, are there more people living in this home, less people living in this home, or the same number of people living in this home? [FORCE RESPONSE]
  a. More
  b. Less
  c. Same
  d. Don't know / Prefer not to say

Q5. Do you have any air conditioning/cooling system(s) in your home?
   a. Yes
   b. No
   c. Don't know

Q6. [If Q5 = Yes] What type of air conditioning/cooling system(s) do you have? [SELECT ALL THAT APPLY]
   a. Central air conditioning
   b. Evaporative (swamp) cooler
   c. Heat pump
   d. Mini-split or "ductless" heat pump
   e. Portable or window AC
   f. Other: __________

Q7. Has your home had any significant upgrades in the past two years? Please select "Yes" or "No" for each. [REQUEST RESPONSE]
   a. New windows – YES NO
   b. New doors to the outside (not doors between rooms) – YES NO
   c. New furnace or other heating equipment – YES NO
   d. New air conditioner or other cooling equipment – YES NO
   e. Added insulation – YES NO
   f. Increased the size of the home – YES NO
   g. Anything else? Please describe:

Q8. Has your home had any significant damage in the past two years, such as from earthquakes, fires or floods? [REQUEST RESPONSE]
   a. Yes
   b. No

HCS Improvements – Incidence

Q9. To what extent were each of the following an issue for your household this past year (in 2024)? [REQUEST RESPONSE]

	Major issue	Moderate issue	Minor issue	Not an issue
a. Home is drafty				
b. Indoor temperature is not comfortable during winter				
c. Indoor temperature is not comfortable during summer				
d. Indoor air quality				

e. Noise in my house from my appliances or the outdoors			

Q10. How, if at all, has this changed from the year before? [REQUEST RESPONSE]

	Worse	No Change	Improved
a. Draftiness in the home			
b. Indoor temperature during winter			
c. Indoor temperature during summer			
d. Indoor air quality			
e. Noise in my house from my appliances or the outdoors			

HCS Improvements – Attribution

[Ask if Q10.a. = Improved (for draftiness)]

Q11. From the list below, please identify the reason(s) you think it was less drafty in your home this year (2024) compared to the year before. [SELECT ALL THAT APPLY; ROTATE RESPONSE OPTIONS]

[If more than one reason selected] Please drag and drop the main reason(s) into the box to the right, starting with the primary reason.

	Rank
It's been warmer this year	
It's been cooler this year	
Home was remodeled	
Window caulking and sealing	
New windows and/or doors	
New insulation added	
Other: __________ [ANCHOR]	

[Ask if Q10.b. = Improved (for temperature during winter)]

Q12. From the list below, please identify the reason(s) your indoor air temperature was more comfortable in your home this past winter (December 2023 – February 2024) compared to the winter before. [SELECT ALL THAT APPLY; ROTATE RESPONSE OPTIONS]

[If more than one reason selected] Please drag and drop the main reason(s) into the box to the right, starting with the primary reason.

	Rank
It's been more or less humid	
We've had more or less rain	
It's been warmer this winter	
Occupants of the home changed (more or fewer people, or different people in the home)	
We can afford to heat the home more	
We use a smart thermostat now	
Home was remodeled	
Heating equipment was cleaned, fixed, or tuned up	
New heating equipment was installed	
Heating ducts were fixed	
New portable space heaters	
New window caulking and sealing	
New windows and/or exterior doors	
New insulation added	
Other: __________ [ANCHOR]	

[Ask if Q10.c. = Improved (for temperature during summer)]

Q13. From the list below, please identify the main reason(s) your indoor air temperature was more comfortable in your home this past summer (July – September 2024) compared to the summer before. [SELECT ALL THAT APPLY; ROTATE RESPONSE OPTIONS]

[If more than one reason selected] Please drag and drop the main reason(s) into the box to the right, starting with the primary reason.

	Rank
It's been more or less humid	
We've had more or less rain	
It's been cooler this summer	
Occupants of the home changed (more or fewer people, or different people in the home)	
We can afford to cool the home more	
We use a smart thermostat now	
Home was remodeled	
Air conditioner was cleaned, fixed, or tuned up	
A new air conditioner was installed	

A new evaporative cooler (swamp cooler) was installed	
Cooling ducts were fixed	
New ceiling or room fans	
New window caulking and sealing	
New windows and/or exterior doors	
New insulation added	
Other: _________ [ANCHOR]	

[Ask if Q10.d. = Improved (for indoor air quality)]

Q14. From the list below, please identify the main reason(s) your indoor air quality was better this past year (2024) compared to the year before. [SELECT ALL THAT APPLY; ROTATE RESPONSE OPTIONS]

[If more than one reason selected] Please drag and drop the main reason(s) into the box to the right, starting with the primary reason.

	Rank
It's been more or less humid	
We've had more or less rain	
It's been cooler this summer	
Fewer wildfires	
Less outside pollution (dust, pollen, etc.)	
New air purifier	
Home was remodeled	
Air conditioner was cleaned, fixed, or tuned up	
A new air conditioner was installed	
A new evaporative cooler (swamp cooler) was installed	
Heating equipment was cleaned, fixed, or tuned up	
New heating equipment was installed	
New ceiling or room fans	
New window caulking and sealing	
New windows and/or exterior doors	
New insulation added	
Other: _________ [ANCHOR]	

[Ask if Q10.e. = Improved (for noise in the home)]

Q15. From the list below, please identify the main reason(s) it was less noisy in your home this past year (2024) compared to the year before. [SELECT ALL THAT APPLY; ROTATE RESPONSE OPTIONS]

[If more than one reason selected] Please drag and drop the main reason(s) into the box to the right, starting with the primary reason.

	Rank
Home was remodeled	
Occupants of the home changed (more or fewer people, or different people in the home)	
Behavior of occupants in the home has changed (e.g., less noise from household members)	
Air conditioner was cleaned, fixed, or tuned up	
A new air conditioner was installed	
A new evaporative cooler (swamp cooler) was installed	
Heating equipment was cleaned, fixed, or tuned up	
New heating equipment was installed	
New ceiling or room fans	
New window caulking and sealing	
New windows and/or exterior doors	
New insulation added	
New laundry equipment (washer and/or dryer)	
Water heater was cleaned, fixed, or tuned up	
Water heater was insulated	
New water heater	
Other: _________ [ANCHOR]	

Valuation Intro

The next few questions ask you about the value you place on different home conditions. The information will be used to understand how households value programs offered by [IOU] to its customers. Although questions ask about your "willingness to pay" for various conditions, your responses will be used for research purposes ONLY and <u>**will not impact your bill in any way**</u>.

Willingness-to-Pay Valuation Questions

Willingness-to-Pay to Retain [Intro shown if Q10.a., Q10.b., Q10.c., Q10.d., or Q10.e. = Improved]

[Ask if Q10.a. = Improved (for draftiness)]

Q16. You mentioned that your home seems **less drafty** than last year. Would you be willing to **pay $5 more** on your utility bill each month to ensure your house remained less drafty (than before)? [REQUEST RESPONSE]
   a. Yes
   b. No

Q17. [If Q16 = Yes] Would you be willing to **pay [Q17_$] more** on your utility bill each month to ensure your house remained less drafty (than before)? [REQUEST RESPONSE]
   a. Yes
   b. No

Q18. [If Q16 = No] Would you be willing to **pay [Q18_$] more** on your utility bill each month to ensure your house remained less drafty (than before)? [REQUEST RESPONSE]
   a. Yes
   b. No

[Ask if Q10.b. = Improved (for temperature during winter)]

Q19. You mentioned your home was **more comfortable** this past winter (2023) compared to the winter before. Would you be willing to **pay $10 more** on your utility bill each month in the winter (January, February and March) to keep the current level of comfort? [REQUEST RESPONSE]
   a. Yes
   b. No

Q20. [If Q19 = Yes] Would you be willing to **pay [Q20_$] more** on your utility bill each month in the winter (January, February and March) to keep the current level of comfort? [REQUEST RESPONSE]
   a. Yes
   b. No

Q21. [If Q19 = No] Would you be willing to **pay [Q21_$] more** on your utility bill each month in the winter (January, February and March) to keep the current level of comfort? [REQUEST RESPONSE]
   a. Yes

b. No

[Ask if Q10.c. = Improved (for temperature during summer)]

Q22. You mentioned your home was **more comfortable** this past summer (2024) compared to the summer before. Would you be willing to **pay $10 more** on your utility bill each month in the summer (July, August and September) to keep the current level of comfort? [REQUEST RESPONSE]
a. Yes
b. No

Q23. [If Q22 = Yes] Would you be willing to **pay [Q23_$] more** on your utility bill each month in the summer (July, August and September) to keep the current level of comfort? [REQUEST RESPONSE]
a. Yes
b. No

Q24. [If Q22 = No] Would you be willing to **pay [Q24_$] more** on your utility bill each month in the summer (July, August and September) to keep the current level of comfort? [REQUEST RESPONSE]
a. Yes
b. No

[Ask if Q10.d. = Improved (for indoor air quality)]

Q25. You mentioned that your indoor air quality seems **better** now than last year. Would you be willing to **pay $5 more** on your utility bill each month to ensure your indoor air quality remained **better** (than before)? [REQUEST RESPONSE]
a. Yes
b. No

Q26. [If Q25 = Yes] Would you be willing to **pay [Q26_$] more** on your utility bill each month to ensure your indoor air quality remained **better**? [REQUEST RESPONSE]
a. Yes
b. No

Q27. [If Q25 = No] Would you be willing to **pay [Q27_$] more** on your utility bill each month to ensure your indoor air quality remained **better**? [REQUEST RESPONSE]
a. Yes
b. No

[Ask if Q10.e. = Improved (for noise in the home)]

Q28. You mentioned it was **less noisy** (from your appliances or from the outdoors) in your home now than last year. Would you be willing to **pay $5 more** on your utility bill each month to ensure **less noise** in your home now (than before)? [REQUEST RESPONSE]

a. Yes
b. No

Q29. [If Q28 = Yes] Would you be willing to **pay [Q29_$] more** on your utility bill each month to ensure your house remained **less noisy** (from your appliances or from the outdoors)? [REQUEST RESPONSE]

a. Yes
b. No

Q30. [If Q28 = No] Would you be willing to **pay [Q30_$] more** on your utility bill each month to ensure your house remained **less noisy** (from your appliances or from the outdoors)? [REQUEST RESPONSE]

a. Yes
b. No

Willingness-to-Pay to Obtain [Intro shown if Q10.a., Q10.b., Q10.c., Q10.d., or Q10.e = Worse or No Change]

[Ask if Q10.a. = Worse or No Change (for draftiness)]

Q31. You mentioned [WORSE: "your home was more drafty than last year. Would"; NO CHANGE: "you have not noticed any recent change in draftiness in your home. **If your home was somewhat drafty**, would"] you be willing to **pay $5 more** on your utility bill each month to make it **less drafty**? [REQUEST RESPONSE]

a. Yes
b. No

Q32. [If Q31 = Yes] Would you be willing to **pay [Q32_$] more** on your utility bill each month to make it **less drafty**? [REQUEST RESPONSE]

a. Yes
b. No

Q33. [If Q31 = No] Would you be willing to **pay [Q33_$] more** on your utility bill each month to make it **less drafty**? [REQUEST RESPONSE]

a. Yes
b. No

[Ask if Q10.b. = Worse or No Change (for temperature during winter)]

Q34. You mentioned [WORSE: “your indoor temperature was less comfortable in winter than before. Would”; NO CHANGE: “you have not noticed any recent change in your indoor temperature during the winter. **If your home was uncomfortably cool** during the winter, would”] you be willing to **pay $10 more** on your utility bill each month in the winter (January, February and March) for **a comfortable temperature in your home during winter**? [REQUEST RESPONSE]

a. Yes
b. No

Q35. [If Q34 = Yes] Would you be willing to **pay [Q35_$] more** on your utility bill each month in the winter (January, February and March) for **a comfortable temperature in your home during winter**? [REQUEST RESPONSE]

a. Yes
b. No

Q36. [If Q34 = No] Would you be willing to **pay [Q36_$] more** on your utility bill each month in the winter (January, February and March) for **a comfortable temperature in your home during winter**? [REQUEST RESPONSE]

a. Yes
b. No

[Ask if Q10.c. = Worse or No Change (for temperature during summer)]

Q37. You mentioned [WORSE: “your indoor temperature was less comfortable in summer than before. Would”; NO CHANGE: “you have not noticed any recent change in your indoor temperature during the summer. **If your home was uncomfortably warm** during the summer, would”] you be willing to **pay $10 more** on your utility bill each month in the summer (July, August and September) for **a comfortable temperature in your home during summer**? [REQUEST RESPONSE]

a. Yes
b. No

Q38. [If Q37 = Yes] Would you be willing to **pay [Q38_$] more** on your utility bill each month in the summer (July, August and September) for **a comfortable temperature in your home during summer**? [REQUEST RESPONSE]

a. Yes
b. No

Q39. [If Q37 = No] Would you be willing to **pay [Q39_$] more** on your utility bill each month in the summer (July, August and September) for **a comfortable temperature in your home during summer**? [REQUEST RESPONSE]
   a. Yes
   b. No

[Ask if Q10.d. = Worse or No Change (for indoor air quality)]

Q40. You mentioned [WORSE: "worse indoor air quality than last year. Would"; NO CHANGE: "you have not noticed any recent change in indoor air quality. **If the air quality in your home was moderate**, would"] you be willing to **pay $5 more** on your utility bill each month **to improve the air quality** in your home?
   a. Yes
   b. No

Q41. [If Q40 = Yes] Would you be willing to **pay [Q41_$] more** on your utility bill each month **to improve the air quality** in your home?
   a. Yes
   b. No

Q42. [If Q40 = No] Would you be willing to **pay [Q42_$] more** on your utility bill each month **to improve the air quality** in your home?
   a. Yes
   b. No

[Ask if Q10.e. = Worse or No Change (for noise in the home)]

Q43. You mentioned [WORSE: "worse noise in your house than last year. Would"; NO CHANGE: "you have not noticed any recent change in the noise in your house. **If the regular noise in your home from your appliances or from the outdoors was somewhat noisy**, would"] you be willing to **pay $5 more** on your utility bill each month **to reduce the level of noise**?
   a. Yes
   b. No

Q44. [If Q43 = Yes] Would you be willing to **pay [Q44_$] more** on your utility bill each month **to reduce the level of noise**?
   a. Yes
   b. No

Q45. [If Q43 = No] Would you be willing to **pay [Q45_$] more** on your utility bill each month **to reduce the level of noise**?

a. Yes
b. No

Conjoint Valuation

Next, we're going to ask you to choose between different scenarios related to comfort in your home. Each scenario has two options (A or B), including a **hypothetical payment to you** that you would receive as a **credit on your monthly utility bill**. It's important to note that this hypothetical payment would go **to you** in this exercise.

The questions will ask you to please select which scenario you prefer – A or B – even if neither is ideal for you. Here are definitions to consider as you select scenarios:

- **Indoor air quality:** The degree of dust, pollen, and wildfire smoke that gets into your home even with the windows closed.
- **Indoor temperatures during the [SEASON]:** The degree to which it is comfortable or uncomfortably [TEMP] in your home in the [SEASON].
- **Draftiness:** The drafts or amount of unwanted airflow through closed windows and doors.
- **Noise in your home:** The regular level of noise in your home from your appliances and from outdoors (through your windows and doors).

Note that you will not actually get paid anything, we just want to know which combination is most appealing to you.

[CARDS SHOWN IN RANDOM FASHION AS PRESCRIBED BY EVERGREEN IN THE SAMPLE FILES; SHOW 4 CARDS PER PARTICIPANT; EXAMPLE CARDS PROVIDED BELOW]

	Scenario A	**Scenario B**
Monthly utility bill credit to you:	$1	$10
Indoor air quality	Good indoor air quality	Moderate indoor air quality
Indoor temperatures during the summer	Uncomfortably warm	Comfortable indoor temperature
Draftiness	Drafty	Little to no drafts
Noise in your home	Very little noise	Some noise
Please choose A or B	[ ]	[ ]

	Scenario A	Scenario B
Monthly utility bill credit to you:	$10	$25
Indoor air quality	Good indoor air quality	Moderate indoor air quality
Indoor temperatures during the summer	Comfortable indoor temperature	Uncomfortably warm
Draftiness	Drafty	Little to no drafts
Noise in your home	Some noise	Very little noise
Please choose A or B	[ ]	[ ]

	Scenario A	Scenario B
Monthly utility bill credit to you:	$10	$25
Indoor air quality	Moderate indoor air quality	Good indoor air quality
Indoor temperatures during the summer	Comfortable indoor temperature	Comfortable indoor temperature
Draftiness	Little to no drafts	Drafty
Noise in your home	Very little noise	Very little noise
Please choose A or B	[ ]	[ ]

Health Impacts – Incidence

To help us better understand the needs and ways [IOU] may be able to help your household, we'd like to know about a few health conditions you or other members of the home experience.

Q46. Has anyone in your household been diagnosed by a doctor or other health care professional with any of the following conditions:

- Asthma
- Arthritis
- COPD

- Autoimmune Diseases (e.g., Lupus, MS)

a. Yes
b. No
c. Don't know / Prefer not to say

Q47. [If Q46 = Yes] How, if at all, have symptoms changed over the past year?
a. Symptoms are worse
b. No change
c. Symptoms have improved
d. A mix (some have improved, some are worse)
e. Don't know / Prefer not to say

Health Impacts – Attribution

[Ask if Q47 = "c" (Improved) or "d" (A Mix) for each selected at Q46]

Q48. From the list below, please identify the main reason(s) the symptoms improved. [SELECT ALL THAT APPLY; ROTATE RESPONSE OPTIONS]

[If more than one reason selected] Please drag and drop the main reason(s) into the box to the right, starting with the primary reason.

Due to…	Rank
Better air quality in my home	
More comfortable indoor temperature during summer months.	
More comfortable indoor temperature during winter months	
Reduced draftiness in the home	
Use of a new medicine or medicines	
A recent medical procedure	
A new medical device in the home	
Other symptom management has helped	
A change in who lives in my home	
Other: _______________ [ANCHOR]	

Don't know / Prefer not to say

Q49. Finally, does anyone in your household regularly smoke tobacco in your home? [FORCE RESPONSE]

a. Yes – most days or every day
b. Yes – occasionally
c. No
d. Don't know / Prefer not to say

End Screen. Thank you for taking the time to complete this survey. We will send you your $25 e-gift card to the email you provided within 2-3 business days.

Appendix E: Recruitment Materials

The postcard distributed to SCE customers is provided below. This is the English version of the postcard.

Thank you in advance for your help with this important research!

Your household is one of only a small number of households selected to complete this survey, so your feedback will be invaluable. To be one of the 340 SCE customers to receive the **$25 e-gift card**:

- Scan the QR code or type in the URL.
- Complete a brief online survey.

Scan the QR code or use the URL to take the survey:

https://tinyurl.com/#######

YOUR CODE IS: ######

If you have any questions, please call 1(800) 392-0131

La encuesta también está disponible en español.

E&W Research
465 California Street, Suite 810
San Francisco, CA 94104

«customer_name_proper»

«address_proper»

«city_proper», «state» «zip»

You are one of a small number of SCE customers selected to provide information about your use of several appliances in your home.

- The survey should take less than 15 minutes and may be done online or over the phone.
- Your responses will be kept anonymous.
- **You will receive a $25 e-gift card to thank you for your input.**
- Additional details on how to participate are provided on the back of this card.

E&W Research is an independent survey firm working with SCE to improve their customer programs and services.

The email distributed to SCE customers is provided below. This is the English version of the postcard.

Subject: Requesting your feedback for California's utility companies

On behalf of The California Public Utilities Commission (CPUC) and SCE, we'd like to hear from you. Your household is one of only a handful of households selected to complete this brief survey. Your responses will be instrumental in helping improve SCE's customer programs and services.

To thank for providing feedback, you may select a $25 gift card from one of many options after the survey is completed.

The online survey generally takes about 15 minutes and includes questions primarily associated with the heating and cooling needs of your household. Your responses will be confidential, and responses will be combined when reported. No individual responses will be shared.

Following the online survey, you will receive an email with details on how to select and receive your $25 gift card.

Note that we will close the survey after 340 responses, so please complete the survey ASAP to ensure you receive the $25 compensation.

Please **click the link below** to complete the survey.

[LINK]

If you have any questions, please call 1(800) 392-0131.

La encuesta también está disponible en español.

Appendix F: Literature Review

MEMORANDUM

Date: May 10, 2024

To: Carol Edwards, Southern California Edison, and Non-Energy Impacts Study Team

From: Kevin Price, Evergreen Economics
Greg Clendenning and Ferit Ucar, NMR

Re: Non-Energy Impacts Study – Health, Comfort and Safety NEIs Literature Review

This memorandum summarizes the literature review conducted as part of the 2023-2025 Non-Energy Impacts Study conducted by the Evergreen Team on behalf of Southern California Edison (SCE) and the NEI Study Team.

Introduction

Our literature review focuses on two types of non-energy impacts (NEI) studies:

- NEI studies that have quantified participant health, comfort, and safety (HCS) NEIs for weatherization programs similar to California's ESA program that have been completed within the past 10 to 15 years. Because primary NEI research is relatively rare, we have included NEI studies of both income eligible and market-rate weatherization and retrofit programs.
- NEI studies that have used willingness to pay (WTP), willingness to accept (WTA), or conjoint analysis approaches to quantify NEIs that provide methodological guidance to the current study.

Summary of Findings

The literature review investigated HCS-related NEIs and determined that the HCS impacts that appear most frequently in the literature and may result from ESA program participation:

- Indoor air quality (e.g., reduced infiltration of wildfire smoke)
- Comfort in the summer months
- Comfort in the winter months
- Noise impacts (reduced outside noise, increased or decreased noise from new equipment)

- Health impacts (e.g., frequency/intensity of colds, effects on asthma, allergies, arthritis)
- Changes in humidity or dampness
- Change in the presence of mold
- Home safety

Additionally, the literature review highlighted the importance of methods selection. For an initial, primary-research based investigation into HCS-related NEIs, it is appropriate to use stated preference methods. This includes Willingness to Pay (WTP), Willingness to Accept (WTA), and Conjoint Analysis. If HCS NEIs from program participation are determined to exist and have value, then it may be appropriate to conduct focused follow-up research using other methods to go deeper. For example, targeted research on specific subgroups or on certain measure types (or groups of measures) could uncover additional insights and could be used to refine NEI valuations. This is an approach that has been adopted by some other states with active NEI research, such as Massachusetts and Connecticut.

Recent HCS NEI Literature Review Findings

The recent California NEI studies led by SERA et al. and APPRISE rely on outdated literature reviews for many of the NEI values. Nearly all current HSC NEI values leverage findings from a 2010 NEI study from Xcel Energy of Colorado,[21] and the NEI values are not based on new primary data collection within California. More recent studies, primarily conducted in the northeastern United States, have generally relied on a multi-methods approach that often included some combination of (1) a contingent valuation approach, where respondents were asked to place a value on the NEIs they experience such as improved comfort, reduced noise and some health impacts, (2) a self-reported direct measurement of health impacts, such as impacts on asthma triggers and other ailments, and (3) secondary data and literature to identify and monetize NEI values. Table 24 provides a summary of the studies included in this literature review and the methodological approaches used in each study.

Table 24: Methodological Approaches of HSC NEI Literature Reviewed

	Method			
Study	Contingent Valuation	Self-Reported Direct Measurement	Secondary Data and Algorithms	Conjoint Analysis
Connecticut X1942C Cross-Cutting NEI Study – HES & HES-IE NEIs (2023)	X	X	X	

[21] Skumatz, L., "NEBs Analysis for Xcel Energy's Low Income Energy Efficiency Programs", Prepared for Xcel Energy, Denver CO, May 2010.

Connecticut X1942B Cross-Cutting NEI Study – Residential Heat Pump and Heat Pump Water Heater NEIs (2023)	X	X	X	
Massachusetts Low-Income Multifamily Health- and Safety-Related NEIs Study (2021)		X	X	
Massachusetts Residential Heat Pump NEIs Study (2023)			X	
Evaluation of the Weatherization Assistance Program; Delaware Department of Natural Resources and Environmental Control (2020)	X			
Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) (2011)	X		X	
NYSERDA Non-Energy Impacts (NEI) Evaluation (2006)	X			X
National Evaluation of the Weatherization Assistance Program (WAP), 2008-09 Program Years: Health and Household-Related Benefits Attributable to the Weatherization Assistance Program (2014)		X	X	

Connecticut X1942C Cross-Cutting NEI Study – HES & HES-IE NEIS (2023)[22]

As part of a series of NEI studies conducted for the Connecticut Energy Efficiency Board, the 2023 NEI study of the Home Energy Solutions (HES) and Home Energy Solutions – Income Eligible (HES-IE) programs sought to quantify NEIs for HES and HES-IE program participants who installed air sealing and insulation. This study used web surveys to collect data to quantify the NEIs and the goal of the analysis was to estimate NEI values for each measure and NEI category. The study used a combination of a contingent valuation approach for non-health related impacts, such as reduced noise and improved comfort, and self-reported direct measurement of health impacts, such as impacts on asthma triggers and other ailments.

The 2023 study was a follow-up to the 2016 HES/HES-IE Process Evaluation study (R4) that found participants experienced positive net NEIs from participating in the program, including comfort and safety NEIs. The 2016 study recommended the program consider structuring future evaluation

[22] NMR Group. 2023. X1942C Cross-cutting NEI Study – HES & HES-IE NEIs. Prepared for the Connecticut Energy Efficiency Board. https://energizect.com/media/11431

efforts to estimate measure specific NEI values that could be added to program cost-effectiveness testing. Table 25 presents the quantified NEIs for air sealing and insulation for CT's HES/HES-IE program. Most respondents had both air sealing and insulation installed together, so it was not possible to develop individual NEIs for each measure. A regression analysis did not find any statistical differences in insulation and air sealing total NEI values. More detailed results are summarized in Appendix A.1.

Table 25: 2023 CT HES and HES-IE Summary of NEIs for Air Sealing & Insulation* (Annual NEI Value per Average Participant)

NEI	HES (n=77)	HES-IE (n=63)	Average (n=140)
Air quality in the home	$15.76	$29.06	$21.75
Change in humidity or dampness	$26.61	$49.25	$36.80
Change in mold	$15.76	$26.17	$20.45
Comfort in the summer	$105.20	$53.62	$81.99
Comfort in the winter	$114.31	$63.38	$91.39
Noise heard from inside home	$19.42	$35.95	$26.86
Noise heard from outside home	$19.41	$41.33	$29.28
Sub Total	**$316**	**$299**	**$309**
Asthma		$0.75	
Allergies		$11.40	
Colds/Viruses		$1.86	
Sinusitis		$1.42	
Missed work	$2.99	$3.78	$3.35
Missed school		$10.78	
Health NEIs Sub Total	**$29**	**$30**	**$30**
Total Value**	**$346**	**$329**	**$338**

*NEIs are for participants who received incentives for air sealing and insulation through the program. NEI values are in 2020 dollars.

**Values may not sum up to total due to errors in rounding.

Identifying NEIs

The CT HES & HES-IE NEI study identified specific NEIs to be quantified for air sealing and insulation installations. The following list summarizes down the rationale for the NEIs identified in the study:

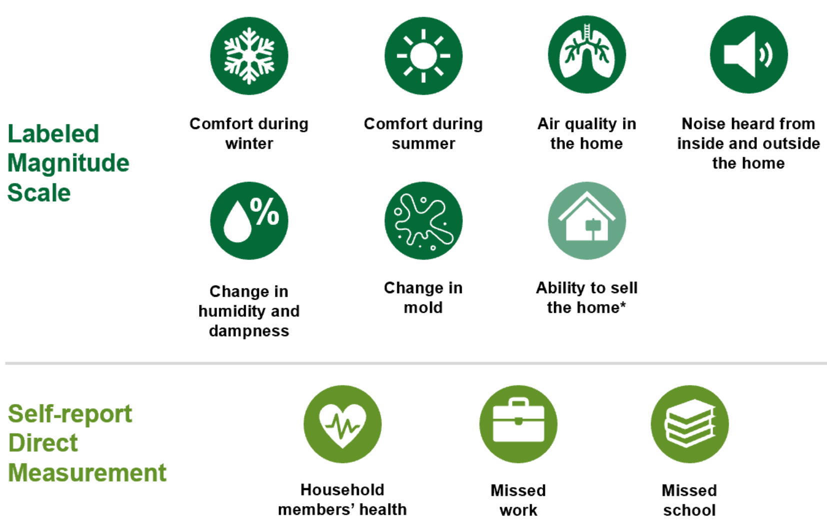
- Comfort in the summer – Adding air sealing and insulation can provide cooling-related comfort by keeping cold air from escaping or hot air and moisture from entering.
- Comfort in the winter – Adding air sealing and insulation can provide heating-related comfort by keeping heat from escaping or cold air and moisture from entering.

- Outdoor noise heard from outside and inside the home – Adding insulation can reduce the amount of noise traveling through the walls within the home as well as outside noise coming into the home. Air sealing can also reduce the amount of outside noise entering the home.
- Air quality in the home – Air sealing and insulation tighten up the home by reducing air flow which can lower the air quality in a home but also reduce the infiltration of outdoor air pollutants into the home.
- Change in humidity and dampness – Reduced air flow in a home can cause an increase in humidity and dampness when moisture gets trapped without adequate ventilation.
- Change in mold – Reduced air flow in a home can also cause an increase in mold when moisture gets trapped without adequate ventilation. Insulation and air sealing also regulate temperature and prevent moisture from entering a home, inhibiting mold growth.
- Household member's health – Changes in air quality and increased comfort from air sealing and insulation can increase or decrease incidences of illnesses such as asthma, colds/viruses, allergies.
- Missed work and school – Increased or decreased incidence of illnesses from air sealing and insulation can reduce loss of earnings from days of missed work and school.

Quantifying NEIs

The study used a combination of a contingent valuation approach where respondents were asked to place a value on the NEIs they experience using a labeled magnitude scale on non-health related impacts, such as reduced noise and improved comfort, and self-reported direct measurement of health impacts, such as impacts on asthma triggers and other ailments. Figure 12 shows the NEIs by their measurement approach.

Figure 12: NEIs by Approach



* Measure excluded from main findings

Labeled magnitude scale (relative valuations)

To develop NEI values, the web survey asked survey respondents if the installation had a positive, negative, or no effect on various non-energy related elements in their households or properties.

For any elements where respondents observed positive or negative impacts as a result of the program, the survey asked them to compare the value of that NEI to the energy savings associated with their participation in the HES or HES-IE program. The survey also asked respondents to identify overlapping NEIs to avoid double counting NEI benefits. Furthermore, the survey asked the respondents to consider the net impacts of the NEIs combined. The analysis used these inputs to estimate NEI dollar values.

Self-report Direct Measurement of Changes in Occurrences

For health impacts, the web survey asked respondents for the number of times they had to seek medical care for specific health ailments in the year before and the year after participating in the program. The survey also asked whether the number of days of work and school missed increase, decrease, or stayed the same.[23] The analysis used these inputs to calculate the avoided cost per occurrence of specific illnesses and loss of earnings from missed work and school.

Connecticut X1942B Cross-Cutting NEI Study – Residential HP and HPWH NEIs (2023)[24]

As part of a series of NEI studies conducted for the Connecticut Energy Efficiency Board, the NMR study team conducted a study to quantify NEIs from residential heat pump (HP) and heat pump water heater (HPWH) program participants who did not participate in the Home Energy Solutions (HES) program. This study collected data from participant end-users to quantify NEIs for mini-split heat pumps (MSHPs), central air source heat pumps (CASHPs), ground source heat pumps (GSHPs), and heat pump water heaters (HPWHs). The study also stratified program participants by replacement type, early replacement (ER) and replace on failure (ROF), for MSHPs and HPWHs. The study used a combination of a contingent valuation approach to quantify non-health related impacts, such as reduced noise and maintenance, and self-reported direct measurement of health impacts, such as impacts on asthma triggers and other ailments.

Table 26 presents a summary of the quantified participant NEIs on an annual basis, which are expected to last through the life of the heat pump and HPWH measures. Participants who received

[23] While the survey included residential program participants who received air sealing and insulation equipment incentives from the HES and HES-IE programs between 2017 and 2019, the period of survey fielding coincided with the pandemic that shifted the workforce to remote working and students to remote learning. This period of remote working and learning may influence responses that may not be reflective of times of regular in office work and in-person learning.

[24] NMR Group. 2023. X1942B Cross-cutting NEI Study – Residential HP & HPWH NEIs. Prepared for the Connecticut Energy Efficiency Board. https://energizect.com/sites/default/files/documents/X1942BReport%20Final.pdf

incentives for heat pumps and/or HPWHs through the program experienced positive net impacts from the program. The non-health NEIs for heat pumps have average annual value of $446 ($475 including health NEIs), which is 123% of the value of their expected energy savings (based on an average expected annual savings of 1,723 kWh per participant). Annual non-health NEIs for HPWHs is $220, which is 56% of the value of their expected energy savings (based on an average expected annual savings of 2,348 kWh per participant).

Table 27 presents the non-health NEIs as a share of expected energy savings. More detailed results are summarized in Appendix A.2.

Table 26: Summary of Monetized NEIs – Measure Based*

(Annual NEI per Average Participant that Installed the Measure)

			MSHP (n=170)			Heat Pumps	HPWH (n=70)		
NEIs	CASHP (n=12)	GSHP (n=6)	ROF (n=69)	ER (n=101)	Average	Average (n=188)	ROF (n=48)	ER (n=22)	Average
Appearance of the home	$67.94	$132.21	$41.95	$69.89	$58.54	$61.49	$36.95	$23.47	$32.71
Comfort during summer	$132.76	$45.85	$51.83	$75.33	$65.79	$69.43	$131.68	$66.66	$111.24
Comfort during winter	$124.05	$37.43	$86.13	$88.09	$87.29	$88.05	NA	NA	NA
Equipment maintenance	$12.78	$36.95	NA	$44.84	$26.64	$26.08	NA	$56.97	$17.90
Equipment noise	$51.46	$148.53	$47.69	$88.83	$72.13	$73.25	$-89.93	$-24.14	$-69.25
Equipment reliability	$13.53	$7.87	NA	$68.86	$40.91	$38.11	NA	$52.34	$16.45
Frequency of fuel deliveries	$2.15	$105.03	$29.14	$20.39	$23.94	$25.14	$34.40	$67.08	$44.67
Home safety	$50.09	$132.68	$62.98	$43.72	$51.53	$54.03	$23.14	$35.24	$26.94
Other impacts	$5.57		$7.71	$13.11	$10.92	$10.23	$47.03	$21.92	$39.14
Sub Total	**$460.31**	**$646.56**	**$327.42**	**$513.05**	**$437.70**	**$445.82**	**$183.25**	**$299.55**	**$219.80**
Asthma						$2.29			
Allergies						$7.01			
Colds/viruses						$0.33			
Sinusitis						$1.98			
Missed work						$15.18			
Missed school						$2.71			
Sub Total						**$29.50**			
Total	**$460.31**	**$646.56**	**$327.42**	**$513.05**	**$437.70**	**$475.32**	**$183.25**	**$299.55**	**$219.80**

*NEIs are for participants who received incentives for heat pumps and/or HPWHs through the program and experience net impacts from the program. NEI values are in 2020 dollars.

Table 27: Summary of non-health NEI Percent of Measure Savings*

(Savings per Average Participant)

NEIs	CASHP (n=12)	GSHP (n=6)	MSHP (n=170) ROF (n=69)	MSHP (n=170) ER (n=101)	MSHP (n=170) Average	Heat Pumps Average (n=188)	HPWH (n=70) ROF (n=48)	HPWH (n=70) ER (n=22)	HPWH (n=70) Average
Appearance of the home	13%	24%	8%	17%	13%	14%	9%	8%	9%
Comfort during summer	26%	6%	23%	22%	22%	22%	29%	17%	26%
Comfort during winter	25%	6%	21%	22%	21%	21%	NA	NA	NA
Equipment maintenance	6%	7%	NA	9%	5%	5%	NA	13%	4%
Equipment noise	8%	27%	13%	28%	22%	22%	-14%	-6%	-12%
Equipment reliability	6%	2%	NA	22%	13%	13%	NA	18%	6%
Frequency of fuel deliveries	0%	19%	10%	8%	8%	8%	7%	11%	8%
Home safety	10%	25%	25%	12%	17%	17%	6%	8%	6%
Other impacts	1%	NA	2%	4%	3%	3%	10%	6%	9%
Total Value	**95%**	**116%**	**101%**	**142%**	**126%**	**123%**	**47%**	**75%**	**56%**

*NEIs are for participants who received incentives for heat pumps and/or HPWHs through the program and experience net impacts from the program.

Quantifying NEIs

This study used a combination of a contingent valuation approach where respondents were asked to place a value on the NEIs they experienced using a labeled magnitude scale on non-health related impacts, such as reduced noise and maintenance, and self-reported direct measurement of health impacts, such as impacts on asthma triggers and other ailments.

Labeled magnitude scale. To develop NEI values, the web survey asked survey respondents if the installation had a positive, negative, or no effect on various non-energy related elements in their households or properties.

For any elements where respondents observed positive or negative impacts as a result of the program, the survey asked them to compare the value of that NEI to the energy savings associated with their participation in the retail HVAC program. The survey also asked respondents to identify overlapping NEIs to avoid double counting NEI benefits. Furthermore, the survey asked the respondents to consider the net impacts of the NEIs combined. The analysis used these inputs to estimate NEI dollar values.

Self-report direct measurement. For health impacts, the web survey asked respondents to indicate the number of times they had to seek medical care for specific health ailments in the year before and the year after participating in the program. The survey also asked whether the number of days of work and school missed increase, decrease, or stayed the same.[25] The analysis used these inputs to calculate the avoided cost per occurrence of specific illnesses and loss of earnings from missed work and school.

Massachusetts Low-Income Multifamily Health- and Safety-Related NEIs Study (2021)[26]

The objective of this study was to quantify and monetize the health- and safety-related NEIs attributable to improvements in the energy efficiency of multifamily buildings served through the Mass Save® income-eligible coordinated delivery initiative of the Massachusetts Program Administrators (PAs). Monetization entailed valuing the impacts of weatherization services on program recipients by calculating money saved, or the dollar value of costs avoided, due to changes in health and household outcomes and budgets resulting from weatherization.

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[25] While the survey included residential program participants who received heat pump equipment incentives from the HVAC program between 2017 and 2019, the period of survey fielding coincided with the Covid-19 pandemic that shifted the workforce to remote working and students to remote learning. This period of remote working and learning may influence responses that may not be reflective of times of regular in office work and in-person learning.

[26] Three Cubed and NMR Group. 2021. Low-Income Multifamily Health- and Safety-Related NEIs Study (TXC50). Prepared for the Massachusetts Program Administrators. https://ma-eeac.org/wp-content/uploads/TXC50_LIMF-HS-NEIs-Final-Report_2021.08.12.pdf

The study collected data from weatherization program participants and non-participants in Massachusetts, while a partner study collected similar data from program participants and non-participants in Illinois, New Hampshire, New York, Pennsylvania, Rhode Island, Vermont, and Wisconsin. Both studies took a quasi-experimental approach to estimate the causal non-energy impacts of weatherization on low-income households without random assignment. Using a pre-post design, the two studies administered the same set of survey instruments to three groups of residents of affordable multifamily buildings before and after weatherization: a Treatment group, with pre- and post-testing; a Comparison-with-Treatment group, which received its treatment prior to the start of the project; and a Control group. wThe studies supplemented these surveys with information about the mechanical and ventilation systems in the buildings before weatherization and the measures installed during weatherization. The study quantified four of the NEIs the study explored – Arthritis, Thermal Stress (Cold), Home Productivity, and Reduced Fire Risk – that met the Massachusetts adoption criteria (Table 28). More detailed results are summarized in Appendix A.3.

Table 28: Estimated Annual Values for Recommended NEIs Per Housing Unit, with Value of Statistical Life (VSL) as Applicable

NEI Values	Per Year
Arthritis	$49
Thermal Stress (Cold)	$1,426
Home Productivity	$49
Reduced Fire Risk	$13
Annual Total of Recommended NEIs per Weatherized Housing Unit	**$1,537**

Two of the monetized NEIs – reduced Thermal Stress and Reduced Fire Risk – were calculated with the benefit of avoided deaths using the value of a statistical life (VSL).[27] To monetize this benefit, the study adopted the VSL value recommended by the U.S. Department of Transportation (DOT)

[27] The value of human life (VSL) is a measure used to compare regulatory costs to benefits. See OMB Circular A-4 for more discussion on VSL or visit U.S. EPA's website: https://www.epa.gov/environmental-economics/mortality-risk-valuation#whatisvsl

($9.6 million), which is similar to the VSL value used by the U.S. Environmental Protection Agency (EPA).[28,29,30]

It is important to note that the VSL does not refer to the value of a life but rather to the value of a *change in one's mortality risk*. As guidance from the DOT notes, the VSL is "defined as the additional cost that individuals would be willing to bear for improvements in safety (reductions in risks) that, in the aggregate, reduce the expected number of fatalities by one ... what is involved is not the valuation of life as such, but valuation of reductions in risk."[31]

Cost benefit analyses conducted at the federal level do not typically distinguish benefits accrued to individuals or households apart from society as a whole. However, in this study, the benefit of avoided deaths is applied as a household benefit.

Massachusetts Residential Heat Pump NEIs Study, MA21X21-E-RHPNEI (2023)[32]

This study used existing Massachusetts studies, a recently completed Connecticut NEI study for heat pumps (see Section 1.2 Connecticut X1942B Cross-cutting NEI Study – Residential HP & HPWH NEIs (2023)), and other secondary data to assess and update the NEIs that the Massachusetts Program Administrators (PAs) currently claim for their market-rate heat pump measures as well as identify and monetize new participant NEIs. The NEI values from this study also apply to

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[28] The DOT issues annual updates to the VSL to adjust for changes in prices and real incomes. Federal agencies, including DOT and U.S. EPA, use the VSL to assess the benefits of their regulations or policies intended to reduce deaths or fatalities (e.g., from traffic accidents or adverse environmental events/conditions). The last known VSL published by the EPA is $7.4M (2006 dollars), which is a central estimate to be inflated to the year of analysis. An article published in the journal *Risk Analysis* provides an overview of VSL application in federal regulatory analyses and states that (1) EPA's and DOT's estimates have become remarkably similar as both now use central VSL estimates somewhat above $9 million; (2) this increasing similarity appears to result at least in part from reliance on the same type of research (wage risk studies); and (3) DOT has updated its guidance more frequently than EPA (Robinson and Hammitt 2015).

[29] At the time of the WAP evaluations, U.S. government agencies were using values ranging from $5-9 million in regulatory cost-benefit analysis. The WAP National Evaluation used a conservative VSL of $6M (in 2000 dollars) adjusted for inflation to $7.5M in 2008 dollars. For the MA LI SF NEI study, the VSL of $7.5M used in the national WAP evaluation was updated to $9.6M, a 2016 VSL recommended by the U.S. DOT. The DOT's Office of General Council reports updated VSLs in the memo Guidance on Treatment of the Economic VSL in U.S. DOT Analyses. The last known published memo was in 2016.

[30] https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20a%20Statistical%20Life%20Guidance.pdf

[31] https://www.transportation.gov/sites/dot.gov/files/docs/BCA%20Resource%20Guide%202016.pdf

[32] NMR Group, Three Cubed, and DNV. 2023. Residential Heat Pump NEIs Study (MA21X21-E-RHPNEI). Prepared for the Massachusetts Program Administrators. https://ma-eeac.org/wp-content/uploads/MA21X21-E-RHPNEI_Residential-Heat-Pump-NEIs-Study-Final-Report_2023.07.21.pdf

comparable heat pump measures offered through the MA PAs' low- and moderate -income program offerings.

Table 29 presents a summary of the recommended NEIs attributable to the MA PAs' heat pump measures. For thermal stress NEIs, the study assumed the NEI value for central heat pumps is the same as ground-source heat pumps (GSHPs). This is due to there being no available estimates for a non-cooling baseline for GSHPs. The "Applicable Heat Pump Installations" column contains information on the displacement of heating systems. For cooling related NEIs for each heat pump type, the team assigned values based on non-cooling baseline values, i.e., the percentage of participants that would not have installed cooling without the PA-supported heat pump. More detailed results are summarized in Appendix A.4.

Table 29: Recommended NEIs Associated with Heat Pump Installations (Annual)

NEI	Applicable HP Installations	Rec'd Value for 2024 ($/year)	Source
Reduction in unintentional, non-fire related CO poisoning deaths resulting from heat pumps fully displacing combustion furnaces (IAQ)	All heat pumps fully displacing oil, propane, and gas furnaces	$0.34	Secondary Research
Reduction in respiratory illness symptoms resulting from heat pumps fully displacing natural gas furnaces with pilot lights (IAQ)	All heat pumps fully displacing gas furnaces	$14.14	Secondary Research
Heat-related mortality risk (thermal stress)	MSHPs fully/partially displacing electric resistance heat	$115.06	Secondary Research
	MSHPs fully/partially displacing oil, propane, or gas equipment	$93.28	
	Central and ground-source heat pumps fully or partially displacing oil, propane, or gas equipment	$37.82	
Productivity gains due to reduced cognitive impacts from extreme heat (thermal stress)	MSHPs fully/partially displacing electric resistance heat	$21.03	Secondary Research
	MSHPs fully/partially displacing oil, propane, or gas equipment	$17.05	
	Central and ground-source heat pump fully or partially displacing oil, propane, or natural gas equipment	$6.91	
Avoided home fires (fire risk)	All heat pumps fully displacing oil, propane, and gas furnaces	$0.03	Secondary Research
	All heat pumps fully displacing oil, propane, and gas boilers	$0.01	

	All heat pumps fully displacing electric furnaces and boilers	$0.02	
Thermal Comfort, summer	All heat pumps except air-to-water heat pumps fully displacing other heating systems	$69.43	CT Study
Thermal Comfort, winter*	All heat pumps fully displacing other heating systems	$88.05	CT Study
Noise Reduction*	All heat pumps fully displacing other heating systems	$73.25	CT Study
Equipment Maintenance*	All heat pumps fully displacing other heating systems	$26.08	CT Study

*For thermal comfort, winter, noise reduction, and equipment maintenance NEIs, the table shows the values for heat pumps that fully displace other heating systems. The recommended NEI value is 50% of the value shown in the table for heat pumps that partially displace oil, propane, and natural gas furnaces and 60% of the value shown in the table for heat pumps that partially displace oil, propane, and natural gas boilers. These percentages were calculated as the ratio of delivered fuel savings per home in partial displacement situations to delivered fuel savings per home in full displacement situations, based on the 2021 Energy Optimization Fuel Displacement Impact and Process study.

Research Methodology

The study used a multi-step process to investigate the NEIs associated with residential heat pump installations. The study Team first explored the applicability of adjusting NEIs that are currently claimed by the MA PAs for other heating and cooling systems to heat pumps. The Team then conducted a rapid evidence assessment (REA) to identify secondary sources to identify and monetize additional NEIs associated with the installation of heat pumps in residential settings or update the values for the NEIs extended from other heating and cooling systems to heat pumps.

The Team primarily focused research on literature that includes the following NEIs:

- **Improved indoor air quality (IAQ) and associated health outcomes.** Burning delivered fuels, natural gas, and wood products indoors decreases IAQ by increasing the concentrations of NOx, PM2.5, and VOCs in indoor air.
- **Increased occupant comfort.** Heat pumps may increase occupant comfort for some use cases, such as added cooling, added heating, and when replacing window/wall ACs.
- **Thermal stress.** In addition to comfort, heat pump measures could result in reduced thermal stress during heat waves (hyperthermia) or during winter (hypothermia).
- **Decreased noise.** Heat pumps are less noisy when compared to window/wall ACs and many aging HVAC systems.
- **Decreased risk of CO poisoning.** Burning delivered fuels, natural gas, and wood products on the premises produces CO.
- **Decreased risk of fires/explosions.** Delivered fuels and natural gas have the potential to explode and/or start a housefire due to leaks or faulty equipment. This may also affect participant costs of owners' or renters' insurance.

The Team used the Energy Optimization Fuel Displacement Impact and Process Study (MA20R24-B-EOEVAL)[33] to determine adjustments to the NEIs based on use cases and parameters that can differ across heat pump installations, including the following:

- Displacement[34]: full or partial
- Baseline systems and fuel: heating natural gas/oil/propane or electric resistance heat
- Early replacement (ER) vs. Replace on Failure (ROF)
- Baseline cooling: ducted, window, wall unit, or none
- Added cooling and heating for previously unconditioned spaces
- Housing type: single-family (SF), multifamily (MF)

Literature review. The documents the literature review examined predominantly consisted of peer-reviewed journal articles. The literature review included articles summarizing studies that did not directly monetize NEIs but did provide information that could be used as inputs for monetization. The evaluation Team used a Rapid Evidence Assessment (REA) approach as the framework for this review. REA is a type of evidence review approach that aims to provide an informed conclusion on the volume and characteristics of an evidence base, a synthesis of what the evidence indicates, and a critical appraisal of the evidence.[35] In addition to the REA approach, the Team reviewed a recently completed heat pump NEI study from Connecticut to update NEIs currently claimed by the PAs (e.g., thermal comfort, noise, and equipment maintenance).[36]

Monetization of new NEIs using reviewed literature and secondary data. The Team relied primarily on academic research to identify new NEIs that the PAs could potentially claim as outcomes from their heat pump initiatives. The Team identified several NEIs that could be monetized without collecting primary data. The selection criteria for NEIs that could be monetized without collecting primary data included the level of evidence in the literature, the availability of additional information with which to monetize the impacts, and the ability to link the impacts to heat pump installations. In this study, the Team focused on monetizing NEIs that met the following conditions.

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[33] https://ma-eeac.org/wp-content/uploads/MA20R24-B-EOEval_Fuel-Displacement-Report_2021-10-13_Final.pdf

[34] Full displacement refers to installations in which customers remove their existing fossil fuel or electric resistance baseline heating system and replaces all space heating loads with heat pumps, either for their whole home or for specific heating zones throughout their home. Partial displacement refers to installations in which the existing fuel-fired system is left in place, and either one or multiple heat pumps are installed and displace the use of existing systems for part of the year.

[35] Collins, A.M., Coughlin, D., Miller, J., Kirk, S. 2015. The Production of Quick Scoping Reviews and Rapid Evidence Assessments: A How to Guide. (U.K. REA Guidebook).

[36] NMR Group. 2023. X1942B Cross-cutting NEI Study – Residential HP & HPWH NEIs. Prepared for the Connecticut Energy Efficiency Board. https://energizect.com/sites/default/files/documents/X1942BReport%20Final.pdf .

1. Literature review demonstrates a weight of evidence of an NEI attributable to installing heat pumps in existing homes.
2. Literature review demonstrates a weight of evidence of an NEI attributable to fuel displacement.
3. Literature review demonstrates strong association with a monetizable health outcome.

Evaluation of the Weatherization Assistance Program, Delaware Department of Natural Resources and Environmental Control (DNREC) (2020)[37]

The evaluation of Delaware' Weatherization Assistance Program (WAP) for the 2016 – 2018 program years for the Delaware Department of Natural Resources and Environmental Control (DNREC) included quantification of several participant health and safety NEIs: comfort, noise, and health.

This study surveyed program participant in order to collect data to quantify the NEIs and used a contingent valuation approach for all three NEIs. Participants were first asked if they had experienced the NEI, and if they had experienced it, participants were asked to quantify the NEI in relation to the bill savings attributable to the weatherization. In addition, the study asked respondents to estimate the total, overall NEI values and then took the conservative approach of scaling the individual NEI values to the overall value. This approach corrects for the common finding that the sum of individual NEI values exceeds the overall value reported by participants of the NEIs together due to overlap of the NEIs.

The study included a billing analysis to estimate the bill savings used to monetize the NEIs. The study recommended that for each NEI, DNREC adopt a conservative estimate of the NEIs, the value at the lower bound of the 90% confidence interval (Table 30).

Table 30: Recommended per Participant NEI Values for the Delaware WAP

NEI	$ Per Year
Thermal Comfort	$155
Noise	$43
Health	$38
Annual Total of Recommended NEIs per Weatherized Housing Unit	**$236**

[37] EcoMetric Consulting LLC and NMR Group Inc. 2020. Program Years 2016-2018 Evaluation Report. Prepared for Delaware Department of Natural Resources and Environmental Control (DNREC). https://documents.dnrec.delaware.gov/energy/Documents/2016-2018-DNREC-Evaluation-Report.pdf

Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) (2011)[38]

This study estimated the value of several NEIs through surveys of participants of programs for existing residential and income-eligible homes, using a contingent valuation method, in this case respondents were asked to assign a monetary value to various NEIs compared to the amount of energy savings yielded by the measures they had installed. To correct for the common finding that the sum of individual NEI values exceeds the overall value reported by participants of the NEIs together, the included a question about overall NEI values, then took the conservative approach of scaling the individual NEI values to the overall value (Table 31).

Table 31: Per Participant NEI Values, 2011 Massachusetts NEI Study

NEI	Low-Income, $ Per Year	Non-Low-Income, $ Per Year
Thermal Comfort	$101	$125
Noise	$30	$31
Health	$19	$4
Equipment Maintenance	$54	$124
Durability of Home	$35	$49
Annual Total of Recommended NEIs per Participating Home	**$239**	**$333**

In addition to the NEIs assessed through the contingent valuation method, the study included self-reported direct measurement of health impacts —via reductions in sick days attributed to the energy efficiency retrofits—as well as societal benefits via reduced medical costs due to reductions in incidences of heat stress, hypothermia, and asthma. Because of the extremely small number of respondents reporting program induced changes in health, the study did not recommend using results from this method.

NEIs estimated from surveys relied on two samples:

- A survey of 213 low-income households whose homes were retrofitted by the PAs programs between July 1, 2009 and June 30, 2010
- A survey of 209 non-low-income households whose homes were retrofitted by the PAs programs between July 1, 2009 and June 30, 2010

[38] NMR Group. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for the Massachusetts Program Administrators. https://ma-eeac.org/wp-content/uploads/Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-1.pdf

In order to examine potential differences in participant NEI values due to the types of measures installed, the study stratified the residential and low-income residential samples according to the measures installed in their homes, with the three strata representing homes retrofitted with shell measures, or with heating and cooling measures, or with shell plus heating and cooling measures.[39] Because program participants can participate in multiple programs with the same program administrator (PA) or across multiple PAs, the study aggregated all measures installed in a participant's home across all of the PAs programs, plus the energy savings associated with the measures.

Using PA data of the estimated energy savings associated with each efficiency measure installed, the study estimated annual bill savings for the sample. Bill savings were estimated by using a population weighted average of gas and electric rates reported on the Web site of the Executive Office of Energy and Environmental Affairs of Massachusetts.[40] Table 32 displays the estimated average annual energy bill savings for the survey respondents, by population and strata. Overall, low-income respondents are expected to save $473 annually and non-low-income respondents are expected to save $673 annually. For the low-income respondents, the shell stratum has the highest average annual energy savings ($583) while for the non-low-income respondents the shell plus heating and cooling stratum has the highest average annual energy savings ($1,275). [41]

Table 32: Estimated Average Annual Energy Bill Savings

Strata	Low-Income	Non-Low-Income
Sample size	***213***	***209***
Shell	$583	$380
Heating and Cooling	$392	$347
Shell plus Heating and Cooling	$445	$1,275
Overall Population	**$473**	**$673**

[39] To be included in the shell stratum, a respondent had to have air sealing or insulation installed. To be included in the heating and cooling stratum, a respondent had to have a heating system, such as furnaces or boilers, or an air conditioning system installed. To be included in the shell plus heating and cooling stratum, a respondent had to have at least one shell measure and one heating and cooling measure installed. Installed measures that were neither shell nor heating and cooling did not affect classification of respondents into strata.

[40] http://www.mass.gov/?pageID=eoeeaterminal&L=5&L0=Home&L1=Energy%2c+Utilities+%26+Clean+Technologies&L2=Electric+Power&L3=Electric+Market+Information&L4=Basic%26%2347%3bDefault+Service&sid=Eoeea&b=terminalcontent&f=dpu_restruct_default_service_fixed_defaul

[41] Estimated annual bill savings ranged from a low of $13.93 to a high of $4,910.74 for non-low-income respondents and from a low of $3.15 to a high of $2,150.81 for low-income respondents.

Quantifying NEIs - Relative Valuation

The Relative Valuation (RV) method of NEI quantification is a type of contingent valuation that involves asking respondents the value of the NEI relative to the bill savings from a program, either in terms of a verbally labeled scale (Labeled Magnitude Scaling) or in percentage or dollar terms (direct scaling or self-reported percentages). For example, an RV survey might ask respondents whether they have experienced changes in the noise level in their home as a result of the program, whether these changes are positive or negative, and whether the value of these changes is higher than, lower than, or about the same as the bill savings from the program (or, for negative changes, how much the value detracts from the bill savings). A follow-up question would ask how much more or less than the bill savings, expressed either as a percentage of bill savings (i.e., self-reported percentages) or as “somewhat” or “very much” more or less than bill savings (i.e., labeled magnitude scaling). While respondents generally answer labeled magnitude scaling questions more quickly than the self-reported percentage, analyzing the data requires an extra step of translating the verbal labels into values using standard equivalence equations. When both methods have been used in a single survey, the results have been similar.

Respondents generally find RV questions easier to answer than another common contingent valuation approach, Willingness to Pay (WTP). The RV results tend to be more consistent within and across studies. A disadvantage is that, across programs, NEI values tend to be correlated with the value of bill savings, which might reflect the fact that higher “anchors” in such survey questions tend to result in higher values, a robust finding in recent survey research (Kahneman and Sugden, 2005).[42] Thus, it is not clear whether higher bill savings results in higher NEI values or whether instead the effect of bill savings on NEI values is an artifact of the survey method, and not reliable evidence that programs with higher bill savings tend to result in more valuable NEIs. Also, when studies have asked respondents to value NEIs relative to bill savings without telling them the average savings amount for the program, results have been less consistent across participants, possibly because different respondents were assuming different levels of bill savings, thus using different values as an anchor with which to decide the value of NEIs. Nevertheless, because this method yields higher response rates and more consistent results than the other methods that have been used, *Relative Valuation* is the most frequently used method in NEI research.

Overall versus Individual NEI Values

Recent NEI research has found that if participants are asked to estimate the value of individual NEIs (i.e., thermal comfort, health, noise, etc.) and then asked to estimate the overall value of all of the individual NEIs together, the sum of the individual values often exceeds the overall value of the NEIs substantially. For example, in Summit Blue’s evaluation of NYSERDA ES Homes program (Barkett et al., 2006), the sum of the individual NEI values is about 250% of bill savings, five times

[42] Kahneman, D. and R. Sugden. (2005). Experienced utility as a standard of policy evaluation. *Environmental & Resource Economics,* 32:161-181.

the average value obtained from the question about the overall value of all the NEIs (roughly 50% of bill savings).

NEI reports typically correct for this divergence between the sum of the NEI values and the overall NEI value by estimating NEI values that are scaled down proportionately, so that they sum to the overall NEI value. This correction is meant to adjust for potential overlap and overestimation of NEIs. Potential overlap and overestimation can be conceptualized in two ways. First, when asking respondents to valuate non-market goods with multiple parts or components, the stated value of the whole is often less than the value of the sum of the parts. This is often referred to as 'part-whole bias' when the values of the individual parts are not adjusted for the value of the whole (Bateman et al., 1996; Brown and Duffield, 1995).[43] Second, when valuating several related things, the stated value of the total is often less than that of the sum of the individual items, often referred to as an "embedding effect" (Baron and Greene, 1996; Brown et al, 1995).[44] There could be any number of explanations for this, but in the case of NEIs it is likely that there is "overlap" among the various NEIs asked about, such that respondents don't conceptualize the individual NEIs as being completely distinct and therefore their values are not completely additive.

Overlap could be occurring among NEIs in a few different possible ways. One way is if there is an implied causal relationship in the respondent's mind between two NEIs, so that it would be redundant to "pay for" each separately. For example, if a respondent thinks that fewer drafts lead to fewer colds and viruses, the respondent might think that both NEIs are valuable, but when combined, the NEIs are less valuable in total because when the respondent 'pays' for fewer drafts the respondent also benefits from fewer colds/viruses. Alternatively, two or more NEIs could be conceptually or experientially similar, so that they share at least some of their perceived meaning. For example, a respondent might perceive comfort, fewer illnesses, and reduced noise as all being different but somewhat overlapping aspects of an overall sense of "well-being," such that the various aspects, when taken separately, add up to more than the overall sense. Finally, one NEI can be considered a subset of another NEI, such that the value of one "contains" the value of another. For example, longer lighting life and even durable home could be perceived as part of

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[43] Bateman, Ian, Alistair Munro, Bruce Rhodes, Chris Starmer and Robert Sugden. 1996. Does Part –Whole Bias Exist? An Experimental Investigation. Working Paper GEC 96-03. Centre for Social and Economic Research on the Global Environment.
Brown, Thomas C and John W. Duffield. (1995) Testing part-whole valuation effects in contingent valuation of instream flow protection. *Water Resources Research* 31(9):2341-2351.

[44] Baron, Jonathan, and Joshua Greene. 1996. Determinants of insensitivity to quantify in valuation of public goods: contribution, warm glow, budget constraints, availability, and prominence. *Journal of Experimental Psychology*. 2(2): 107-125.
Brown, Thomas C. Susan C. Barro, Michael J. Manfredo and George L. Peterson. 1995. Does better information about the good avoid the embedding effect? *Journal of Environmental Management*. 44: 1-10.

"reduced equipment maintenance," such that the value of equipment maintenance includes the value of the other two.

Non-Energy Impacts (NEI) Evaluation of NYSERDA Energy Star Homes Program (2006)[45]

This study by the New York State Energy Research and Development Authority (NYSERDA) estimated NEIs for NYSERDA ENERGY STAR Homes program using two methods, a conjoint analysis (CA) and a contingent valuation approach (relative valuation). This review focuses on the results from the conjoint analysis (Table 33).

Table 33: Annual NEIs, NYSERDA ENERGY STAR Homes Program, Conjoint Analysis

NEI	$ Per Year
Thermal Comfort	$191
Noise	$72
Home Safety	$181
Home Durability	$202
Indoor Air Quality	$156
Annual Total of Recommended NEIs per Weatherized Housing Unit	**$801**

Conjoint Analysis

The *Conjoint Analysis (CA)* survey method, commonly used in marketing research, essentially involves assessing the value of various hypothetical attributes of a product, through multiple questions asking respondents to choose between two hypothetical products, or scenarios with different combinations of the attributes in question. In some of these pairs, a monetary value replaces one of the attribute bundles. These preferences are then analyzed to obtain the monetary value of each of the attributes.[46]

To illustrate the CA approach from the NYSERDA ENERGY STAR Homes program NEI evaluation, one question asked respondents to choose between two different homes. Home 1 was described as having very little noise, standard ventilation (worse air quality), and best installation and

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[45] Summit Blue Consulting and Quantec. 2006. Non-Energy Impacts (NEI) Evaluation. Prepared for the New York State Energy Research and Development Authority.
https://www.aceee.org/files/pdf/conferences/workshop/valuation/MCAC_NEI_Report_06.pdf

[46] For a thorough review of *Conjoint Analysis* see:
Wobus, Nicole, Jennifer Meissner, Brent Barkett, Don Waldman, Kenneth Train, Jennifer Thacker, and Daniel Violette. (2007). Exploring the Application of Conjoint Analysis for Estimating the Value of Non-Energy Impacts. *2007 International Energy Program Evaluation Conference*. Chicago: International Energy Program Evaluation Conference

construction practices (more durable); home 2 had some noise (less quiet), improved ventilation (better air quality) and standard installation and construction practices (less durable).

The main advantage of CA is that it does not require respondents to directly place a value on each of the NEIs. Rather, this method simply asks respondents about their preferences, which arguably is closer to how people evaluate intangibles in their everyday lives. The primary disadvantage of this method for NEI research is that the results reflect the value of NEIs under hypothetical, idealized circumstances, as opposed to value of the NEIs as actually experienced. Another disadvantage of the CA method is that it requires a more lengthy and complex set of survey questions, reducing the number of NEIs that can be evaluated. In addition, the values obtained tend to be substantially higher than those using RV methods. The evaluation of NYSERDA ES Homes (Barkett et al., 2006) found that the average value of overall NEIs from the CV questions was about $300 (50% of bill savings), whereas the value from the CA questions was about $800 (over 130% of bill savings).[47]

National Evaluation of the Weatherization Assistance Program (WAP), 2008-09 Program Years: Health and Household-Related Benefits Attributable to WAP[48]

This study examined and quantified household health and safety NEIs attributable to low-income homes weatherized through the Weatherization Assistance Program. The study hypothesized that weatherizing a home can produce health and safety-related NEIs directly by changing the physical condition of homes. For example, improving the thermal performance of the building envelope, which at minimum increases comfort, also reduces thermal stress experienced by occupants. Additionally, installation of a comprehensive set of weatherization measures can synergistically reduce a plethora of asthma triggers. Weatherization also increases safety through the testing of carbon monoxide (CO) in homes with combustion appliances, the repair and replacement of gas furnaces, and the installation of CO monitors and smoke detectors. Improved health and energy cost savings, in turn, can reduce missed days of work, increase productivity at home, and lead to household budget benefits that then are invested to produce additional household and societal benefits.

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

[48] Tonn, Bruce, Erin Rose, Beth Hawkins, and Brian Conlon. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. Prepared for Oak Ridge National Laboratory. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_345.pdf

The WAP evaluation used a pre-tested occupant survey of a random and representative sample of weatherized single-family[49] homes pre- and post-weatherization, along with a comparison group of homes. The occupant survey was administered in two phases.[50] In phase 1, the survey was administered just prior to the completion of the energy audits in the treatment group households (during calendar year (CY) 2011 and referred to as the Pre-Weatherization Treatment group). The second phase was implemented post-weatherization, approximately 18 months later (during CY 2013). In addition, a group of homes that had already been weatherized one year before the treatment group received weatherization services was surveyed during phase 1; this group of homes served as a post-weatherization comparison group.

The study sought to quantify NEIs primarily through a combination of self-reported direct measurement of health impacts and secondary data on medical and other costs while impacts form CO detectors and avoided fires were monetized with secondary data. For health impacts, the survey asked respondents for the number of times they had to seek medical care for specific health ailments. The study examined the following 12 NEIs:

- Reduced Carbon Monoxide Poisonings
- Reduced Home Fires
- Reduced Thermal Stress on Occupants from Being Too Cold
- Reduced Thermal Stress on Occupants from Being Too Hot
- Reduced Asthma-Related Healthcare and Costs
- Increased Productivity at Work Due to Improvements in Sleep
- Increased Productivity at Home Due to Improvements in Sleep
- Fewer Missed Days at Work
- Reduced Use of High Interest, Short-Term Loans
- Increased Ability to Afford Prescriptions
- Reduced Heat or Eat Choice Dilemma Faced by Pregnant Women
- Reduced Need for Food Assistance

Descriptive statistics generated from the surveys suggest the following post-weatherization benefits:

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[49] Single-family homes surveyed included mobile homes and small multifamily buildings had between two and four units.

[50] For detailed information on the national Occupant Survey, refer to the Occupant Survey Report: Carroll, D., Berger, J., Miller, C., and Driscoll, C. 2014. National Weatherization Assistance Program Impact Evaluation - Baseline Occupant Survey: Assessment of Client Status and Needs. ORNL/TM- 2015/22, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

- The physical condition of homes is improved making the homes more livable;
- Respondents experience fewer 'bad' physical, mental health, and sleep/rest days;
- Respondents and other household members suffer fewer persistent colds and headaches;
- There are fewer instances of doctor and emergency department visits, and hospitalizations related to asthma and thermal stress;
- Households are better able to pay energy and medical bills;
- Households are better able to pay for food; and
- Household use of two kinds of short-term, high interest loans (tax refunds and pawn shops) decreases.

For many of the NEIs evaluated through the national WAP evaluation, the differences between the treatment groups pre- to post-weatherization were statistically significant. Many differences between the Pre-Weatherization Treatment group and the Post-Weatherization Comparison group were also statistically significant.

The estimated NEI values were presented on a dollar per weatherized unit basis, broken down by both societal and household impacts based on health care coverage:

- For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs were categorized as a societal benefit;
- For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (i.e., copayments, deductibles) were categorized as a household benefit; and
- For individuals/occupants that are "uninsured," all of the avoided medical costs was categorized as a household benefit.[51]

Table 34 presents the per unit present value (PV) of the household health and safety NEIs monetized by the study; we did not include NEIs with only societal impacts. The PV of the benefits were estimated over a ten-year time horizon.[52] The study used the discount rate published by the Office of Management and Budget for FY 2013. The study grouped the NEIs into three tiers. Tier 1 estimates were based on observed monetizable outcomes attributable to weatherization (i.e., observed through the national occupant survey, pre- and post-weatherization with a control

[51] Except for asthma as a chronic health condition, where 7% of the total avoided medical costs are OOP costs for uninsured individuals and applied as a household benefit, with the remaining medical costs applied as a societal benefit.

[52] The one exception to the 10-year time horizon was the NEI for installing CO monitors, where present value was calculated over a more conservative 5-year period to reflect the effective useful life of CO monitors of five years.

group) and highly reliable cost data. Tier 2 and 3 estimates all have sound methodologies underlying them but may lack direct observations of improved health or well-being (e.g., based on counts of carbon monoxide monitors installed rather than on survey reports of fewer CO poisoning post-weatherization) and/or require relatively more assumptions. In addition, the household NEIs were estimated without the value of lives saved, which was considered a societal benefit in the national WAP evaluation.

Table 34: Present Value (PV) of Household Health and Safety NEIs Attributable to the WAP, per Housing Unit

NEI	Tier	Household NEIs, Present Value (10-year time horizon)
Asthma	1	$157
Thermal stress (cold)	1	$19
Thermal stress (heat)	1	$15
Reduction in missed days from work	1	$161
CO poisoning	2	$1
Reduction in Use of Short-Term Loans	2	$71
Home fires	3	$63
Increased Productivity at Home Due to Improved Sleep	3	$1,329
PV of Total Household NEIs per Weatherized Housing Unit		**$1,816**

Table 35 provides a summary of the inputs used to monetize each NEI.

Table 35: Summary of Inputs Used to Monetize Household Health and Safety NEIs, National WAP Evaluation

NEI	Summary of NEI Inputs, Household NEIs
Asthma	Reductions in hospitalizations and emergency room visits and the associated avoided out of pocket medical expenses
Thermal stress (cold)	Reductions in medical care required due to thermal stress and the associated avoided out of pocket medical expenses (avoided deaths due to thermal stress was treated as a societal impact)
Thermal stress (heat)	Reductions in medical care required due to thermal stress and the associated avoided out of pocket medical expenses (avoided deaths due to thermal stress was treated as a societal impact)
Reduction in missed days from work	Increase in respondents reporting no sleep problems and secondary data on lost productivity from poor sleep
Increased Productivity at Home Due to Improved Sleep	Increase in respondents reporting no sleep problems and secondary data on lost productivity from poor sleep and average wage rates for housekeeping
Reduction in Use of Short-Term Loans	Reduction in respondents reporting using short-term loans and secondary data on short-term loans

Home fires	Secondary data on fire frequency, causes of home fires, fire damage estimates, and impacts of weatherization activities on fire risks.
CO poisoning	Counts of carbon monoxide monitors installed and secondary data on costs of out-of-pocket medical expenses and impacts of installing CO monitors on medical care.

Massachusetts Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts (NEIs) Study[53]

This study was conducted for the Massachusetts (MA) Program Administrators (PAs), and it leveraged the data and findings from the 2014 report Health and Household-Related Benefits Attributable to the Weatherization Assistance Program (see Section 1.8). The goal of the study was to assess and, if applicable, monetize NEIs from the WAP-study that were also applicable to participants of the PAs' income-eligible weatherization programs. A subset of eight NEIs from the WAP-evaluation was selected based on their direct impact on the household:

1. Reduced asthma (lower medical costs);
2. Reduced cold-related thermal stress (lower medical costs and fewer deaths);
3. Reduced heat-related thermal stress (lower medical costs and fewer deaths);
4. Reduced missed days at work (reduction in lost income);
5. Reduced use of short-term, high interest loans (lower interest payments and loan fees);
6. Increased home productivity due to improvements in sleep (higher productivity for housekeeping);
7. Reduced carbon monoxide (CO) poisoning (lower medical costs and fewer deaths); and
8. Reduced home fires (fewer fire-related injuries, deaths, and property damage).

The national WAP NEI evaluation quantified household NEIs primarily through a combination of self-reported direct measurement of health impacts, such as impacts on health outcomes related to thermal stress or asthma, and secondary data on medical and other costs. The Massachusetts study leveraged the self-reported health impacts from the national WAP evaluation and tailored the secondary data used to monetize the NEIs to Massachusetts- or regional-specific data.

As part of the evaluation, each NEI was analyzed for the extent to which the NEI quantified in the WAP-based evaluation overlapped with, augmented, or superseded the health- and safety-related

[53] Hawkins, Beth, Bruce Tonn, Erin Rose (ThreeCubed), Greg Clendenning and Lauren Abraham (NMR). 2016. Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts Study. Prepared for the Massachusetts Program Administrators. https://ma-eeac.org/wp-content/uploads/Low-Income-Single-Family-Health-and-Safety-Related-Non-Energy-Impacts-Study.pdf

NEIs already claimed by the PAs. The study team provided recommendations for integrating the WAP-based NEIs with any existing NEIs claimed by the Massachusetts PAs.

Underpinning the methodology utilized to estimate the NEIs attributable to the national WAP was a pre-tested, national occupant survey of a random and representative sample of weatherized single-family[54] homes pre- and post-weatherization, along with a comparison group of homes. The occupant survey was administered in two phases.[55] In phase 1, the survey was administered just prior to the energy audits completed in the treatment group households. The second phase was implemented post-weatherization, approximately 18 months later. In addition, a group of homes that had already been weatherized one year before the treatment group received weatherization services was surveyed during phase 1; this group of homes served as a post-weatherization comparison group.

Table 36 presents a summary of the monetized NEIs from the Massachusetts study.

Table 36: Summary of Monetized NEIs, MA LI Health and Safety NEI Study (Annual NEIs per Household)

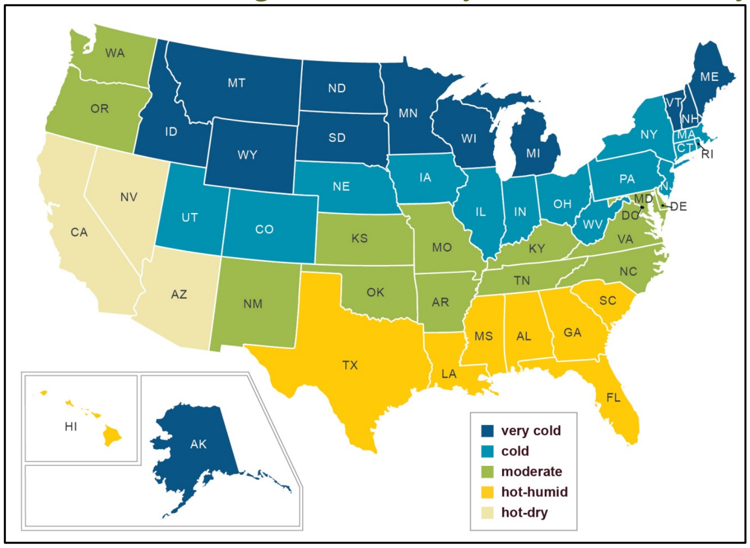
NEI	$ Per Year
Asthma	$9.99
Thermal stress (cold)	$463.21
Thermal stress (heat)	$145.93
Reduction in missed days from work	$149.45
CO poisoning	$36.98
Reduction in Use of Short-Term Loans	$4.72
Home fires	$93.84
Increased Productivity at Home Due to Improved Sleep	$37.75
PV of Total Household NEIs per Weatherized Housing Unit	**$941.87**

[54] Single-family homes surveyed included mobile homes and small multifamily buildings consisting of between two and four units.
[55] For detailed information on the national Occupant Survey, refer to the Occupant Survey Report: Carroll, D., Berger, J., Miller, C., and Driscoll, C. 2014. National Weatherization Assistance Program Impact Evaluation - Baseline Occupant Survey: Assessment of Client Status and Needs. ORNL/TM- 2015/22, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Additional Details of the Analysis for the Massachusetts Low-Income Health- and Safety-Related NEIs

The study limited the analysis to data for households located in the cold region of the U.S. for all NEIs except asthma,[56] which used the full, national sample (Figure 13).

Figure 13: U.S Climate Regions for Analysis of WAP Survey Results



For six of the eight NEIs addressed by this report, the data from the national occupant survey were used as the basis for the monetization approaches as sample size was sufficient to indicate observable impacts from pre- to post-weatherization. For two of the NEIs, carbon monoxide (CO) poisoning and fire prevention, data was collected from local weatherization agencies on the number of CO monitors installed that could reduce the probability of CO poisoning, and the number of smoke detectors installed, as well as other weatherization measures that could reduce the probability of home fires.

To estimate the NEIs that relied on survey data (except for asthma), the study calculated the decrease in health-related outcomes between pre- and post- treatment groups and between pre-treatment and post-comparison groups (i.e., an average of the differences) (see Equation 2). This approach was utilized.

Equation 2

[(Pre-Wx Treatment – Post-Wx Treatment) + (Pre-Wx Treatment – Post-Wx Comparison)] / 2

[56] The study noted that the asthma sample was limited and that asthma prevalence does not vary significantly by climate region.

For asthma, the analysis was limited to a comparison of the pre and post weatherization treatment group (Equation 3) because of differences in the sample characteristics of the asthma populations of the treatment and control group.

Equation 3

Pre-Wx Treatment – Post-Wx Treatment

In order to estimate Massachusetts- specific NEI values, a number of inputs were specified using Massachusetts or regional data rather than national data. Other examples of modifications that were applied to the NEI algorithms from the national WAP evaluation include the following:

- The discount rate was adjusted from the Office of Management and Budget (OMB) rate of 0.1% to a twenty-year discount rate of 0.44%.[57,58]
- The Value of Statistical Life (VSL) was updated from $7.5M[59] to the U.S. Department of Transportation's (DOT) recommended value for 2016 of $9.6M
- The VSL associated with avoided deaths was applied as a household benefit rather than a societal benefit.[60]

Avoided Deaths and the Value of a Statistical Life (VSL)

To monetize the benefit of avoided deaths from thermal stress, CO poisoning, and fire, the VSL was adjusted and updated from the $7.5M (2008 dollars) used in the national WAP evaluation to $9.6M (2015 dollars), as published in the DOT guidance document for 2016.[61] The DOT issues

[57] The national WAP evaluation used the ten-year real treasury interest rate for 2013 (0.1%) from Office of Management and Budget (OMB) to calculate the present value (PV) of the total discounted savings for all NEIs.

[58] The use of a 0.44% discount rate over a period of twenty years to calculate the PV is consistent with the discount rate and the measure life for low-income weatherization used in the MA PAs' Three-Year 2016-18 Plan.

[59] Value of human life, or as economists refer to it as, the Value of Statistical Life (VSL), is a measure used to compare regulatory costs to benefits. At the time of the WAP evaluations, the U.S. government agencies were using values ranging from $5-9 million in regulatory cost-benefit analysis. The WAP National Evaluation used a conservative VSL of $6 million (2000 dollars) adjusted for inflation to $7.5 million in 2008 dollars. See OMB Circular A-4 for more discussion on VSL.

[60] At the time of the report, EPA did not explicitly state that the effect of the VSL costs and benefits should be applied as societal or household impacts; this lack of guidance has resulted in conflicting schools of thought on this matter. Based on consultation with health economists, the WAP National Evaluation chose to apply avoided costs as a societal benefit. However, based on additional research, it is clear that VSL estimates are based on the value that individuals' place on reducing their own mortality risk. Thus, for the Massachusetts study, the study group decided to categorize VSL as a household benefit.

[61] DOT's annual VSL guidance for 2016 was forthcoming at the time of the report (Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analysis). In the interim, the updated VSL is published in DOT's Benefit-Cost Analysis (BCA) Resource Guide, updated March 1, 2016, available at https://www.transportation.gov/sites/dot.gov/files/docs/BCA%20Resource%20Guide%202016.pdf.

annual updates to the VSL to adjust for changes in prices and real incomes. Federal agencies including DOT and U.S. Environmental Protection Agency (EPA) use the VSL to assess the benefits of their regulations or policies intended to reduce deaths or fatalities (e.g., from traffic accidents or adverse environmental events/conditions). At the time of the report, the last known VSL published by the EPA was $7.4M (2006 dollars), which is to be updated to the year of analysis.[62] An article published in Risk Analysis provided an overview of VSL application in federal regulatory analyses and found the following: 1) EPA's and DOT's estimates have become remarkably similar; both now use central VSL estimates somewhat above $9 million; 2) this increasing similarity appears to result at least in part from reliance on the same type of research (wage risk studies); and 3) DOT has updated its guidance more frequently than EPA (Robinson and Hammitt 2015).[63]

It is also important to note that the VSL does not refer to the "value of a life" but rather as the value of a change in one's mortality risk. From the DOT guidance, the VSL is "defined as the additional cost that individuals would be willing to bear for improvements in safety (reductions in risks) that, in the aggregate, reduce the expected number of fatalities by one...what is involved is not the valuation of life as such, but valuation of reductions in risk."

The study also explored whether a different VSL value was being used by regulatory agencies in MA (e.g., MA Department of Transportation (MADOT), MA Department of Environmental Protection (MADEP)), but the study team did not find any in the published literature or through inquiries made to agency personnel. However, the study team did find a 2010 MADOT publication that references the USDOT's 2009 VSL to monetize the value of accidental traffic deaths that can be prevented through improvements to freight infrastructure and operations in the Commonwealth.[64]

Thermal Stress NEIs

Thermal stress caused by extreme indoor thermal conditions (i.e., temperature, humidity, drafts) can have significant adverse effects on health and mortality. According to the Mayo Clinic, the following people are most at risk for heat and cold-related illnesses:

- Elderly persons, pregnant women, and toddlers/infants
- Individuals with chronic medical conditions, mental disorders, or mobility impairments

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DOT's 2015 guidance document, dated June 17, 2015, is available at https://www.transportation.gov/sites/dot.gov/files/docs/VSL2015_0.pdf.

[62] EPA. Mortality Risk Valuation. Available at https://www.epa.gov/environmental-economics/mortality-risk-valuation#whatisvsl.

[63] Robinson, Lisa A. and Hammitt, James K. "Research Synthesis and the Value per Statistical Life," *Risk Analysis*, Vol. 35, No. 6, 2015, p. 1088.

[64] Massachusetts Department of Transportation, Chapter 4, Freight Investment Scenarios, Freight Plan, September 2010, pp. 4-10 through 4-11.

- Any individual with inadequate food, clothing, or heating/cooling systems.

Low-income weatherization specifically targets this high-risk population. Weatherization decreases the chance of an individual being subjected to dangerously cold temperatures by addressing inadequate heating systems and insulation and decreasing excessive drafts in the home; alternatively, weatherization can address inadequate cooling systems and/or ventilation in the home to minimize heat-related illnesses.

The thermal stress NEIs were based on reductions in medical care required due to thermal stress. Because the specific type of medical care needed was not collected by the WAP evaluation, in order to accurately estimate total cost savings associated with the reduction of medical treatment and avoided deaths due to thermal stress, the following steps were taken:

- Secondary data sources were mined to establish the incidence rate, for the general U.S. population, of types of medical treatment used to treat these conditions.[65]
- A ratio based on the incidence of treatment type, from weighted averages over a 5-year period, was applied to the overall percent reduction in seeking medical treatment (Occupant Survey), for both cold and heat-related thermal stress.
- Average cost for each type of medical treatment were mined from the same secondary data source, and multiplied by the incidence of treatment type ratio.
- The percentage of death following hospitalization treatment for both cold and heat-related thermal stress, for general U.S. population, was mined from secondary data source.[66]
- Variables for "payer" (i.e., Medicare, Medicaid, Private/Other Insurance, Uninsured) were identified and isolated in order to group average yearly costs by payer. Average yearly out-of-pocket (OOP) costs were extracted from these costs.

[65] It was assumed that the same national incidence rate for type of treatment could be applied to the WAP population. The study team believed this assumption resulted in a conservative estimate as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions. Therefore, one could argue the potential exists for the WAP population to require the higher-cost treatment (i.e., hospitalizations).

[66] The study took a conservative approach and assumed that the same national rate of deaths following hospitalizations could be applied to the WAP population. The study team believed this was a conservative assumption as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions.

Literature Review Appendix A: Additional Details of NEI Quantification

This appendix provides more detailed results from the studies included in this literature review.

A.1 Connecticut X1942C Cross-Cutting NEI Study – HES & HES-IE NEIs (2023)

A.1.1 Non-Health NEIs

By Program

The total dollar value of all non-health related NEIs is $309 for the average air sealing and insulation end-user. Figure 14 shows the total dollar value of all NEIs per year by program for participants who received incentives for air sealing and insulation. While the HES program has the higher overall NEI value at $316 compared to the HES-IE program at $299, the differences in the total dollar value of the NEIs by program are not statistically significant at the 90% confidence level.

Figure 14: Annual NEI Dollar Value by Program*

(Annual NEI Value per Average Participant that Installed Air Sealing and Insulation)

*Bars and numbers in parentheses show 90% confidence intervals.

Figure 15 shows the corresponding percent of savings by program. On average, respondents value NEIs the same for HES and HES-IE (113%) when compared to the value of their expected energy savings.

Figure 15: Percent of Savings by Program*

*Bars and numbers in parentheses show 90% confidence intervals.

A.1.2 Health NEIs

Annual NEI values per participant attributable to avoided illnesses range from $0.75 to $11.40 ($7.82 to $118.36 lifetime). Table 37 provides the high-level calculation of the annual value per average participant attributable to asthma, allergies, sinusitis, and cold/viruses. The survey yielded very low levels of change in the number of incidences occurring per year. Survey respondents reported low levels of change for the other ailments. The analysis resulted in annual NEI values (per participant) of $0.75 for asthma, $11.40 for allergies, $1.42 for sinusitis, and $1.86 for colds and viruses.

Table 37: Annual and Lifetime NEI Values Per Participant for Reduced Illnesses

	Asthma	Allergies	Sinusitis	Colds/ Viruses
Avoided cost per incidence, adjusted to 2021 dollars* (A)	$284	$684	$249	$35
Avoided out of pocket cost per incident adjusted for insurance coverages** (B)	$108	$259	$95	$13
Change in number of incidents per year*** (C)	0.007 (0.0002, 0.01)	0.044 (0.01, 0.24)	0.015 (0.003, 0.03)	0.140 (0.04, 0.20)
Annual value per average participant attributable to specific avoided illnesses (B×C)	**$0.75 ($0.02, $1.52)**	**$11.40 ($3.11, $19.65)**	**$1.42 ($0.25, $2.55)**	**$1.86 ($0.48, $3.22)**
Lifetime NEI attributable to program measures****	**$7.82 ($0.21, $15.76)**	**$118.36 ($32.31, $204.00)**	**$14.71 ($2.56, $26.50)**	**$19.26 ($5.02, $33.43)**

* Source: Agency for Healthcare Research and Quality. Medical Expenditures Panel Survey, 2021. https://www.meps.ahrq.gov/mepsweb/.

** Avoided out of pocket cost per one incident adjusted for insurance coverages = avoided cost per incidence, adjusted to 2021 dollars × Percent of CT residents uninsured / not covered by health insurance for Northeast × Average percent out of pocket payment (from MEPs). Example Asthma: $284 (A) × 5.9% × 34% = $108 (B)

*** Incidence calculated from survey responses.

**** Lifetime NEI attributable to program measures = Annual value per average participant attributable to avoided illness × weighted average years lifetimes × discount rate. Example Asthma: $0.75 × weighted average years lifetimes × 15 years × 5% = $7.82; 90% confidence intervals in parentheses.

Annual NEI value per participant attributable to avoided missed work is $2.99 for average residential households and $3.78 for low-income households. Table 38 calculates the annual value per average participant attributable to missed work. Respondents reported an average of 0.03 fewer missed worked days after installing air sealing and insulation through the program which equates to an annual avoided cost of $2.99 and $3.78 for average residential and low-income households, respectively.

Annual NEI value per participant attributable to avoided missed school is $10.78. The analysis found a very small (0.13 days) reduction in the average number school days missed, as shown in Table 16, after program participation.

Table 38: Annual NEI Values Per Participant for Missed Work

	Average Residential	Low-Income
Wages per day for average residential household* (A)	$251.68	$145.84
Wages lost per day for households with primary earner (corrected for without sick leave)** (B)	$55.37	$70.00
Change in number of average workdays missed due to program effect (C)***	0.05 (0.02, 0.09)	
Changes in household wages from change in sick days lost from work (B×C)******	**$2.99 ($1.20, $4.78)**	**$3.78 ($1.51, $6.04)**

* Wages per day for average residential household = Median hourly wage for Connecticut for all occupations in 2020 is $31.46 × Hours per workday = $31.46 × 8 = $251.68 (A)
Wages per day for low-income household = Median hourly wage for Connecticut for all occupations in 2020 is $31.46 × Hours per workday = $18.23 × 8 = $145.84 (A)
Source: U.S. Bureau of Labor Statistics. "May 2020 State Occupational Employment and Wage Estimates Connecticut," May 2020, www.bls.gov.
** Wages lost per day for households with primary earner (corrected for without sick leave) = Percent of homes without sick leave in 2020 is 22% × hourly wage for average residential household. $251.68 (A) × 22% = $55.37 (B)
Wages lost per day for households with primary earner (corrected for without sick leave) = Percent of homes without sick leave in 2020 is 22% × hourly wage for low-income residential household. $145.84 (A) × 48% = $70.00 (B)
Source: U.S. Bureau of Labor Statistics. "Employee Benefits in the United States – March 2021." News Release, September 23, 2021, https://www.bls.gov/news.release/pdf/ebs2.pdf, Table 6 (pg. 17).
*** Input from survey responses.
**** 90% confidence intervals in parentheses.

Table 39: Annual NEI Values Per Participant for Missed School

	Missed School Values
Savings from childcare from 1 day of reduced absences* (A)	$83.89
Change in number of average school days missed due to program effects** (B)	0.13 (-0.02, 0.27)
Participant value from changes in sick days lost from school (A×B)* **	**$10.78 ($-1.39, $22.96)**

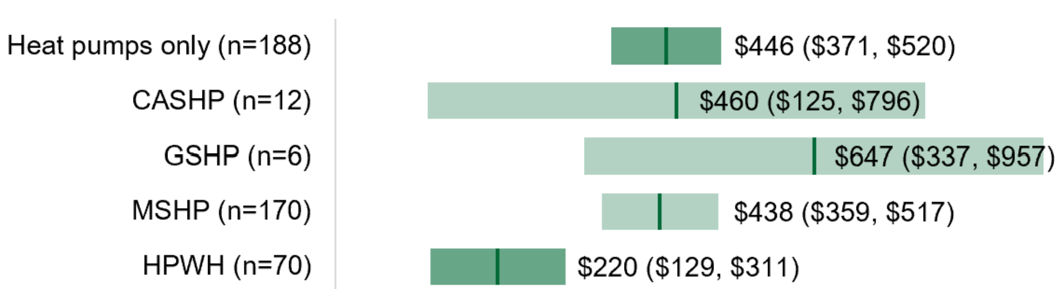
* Savings from childcare from 1 day of reduced absences = Family Childcare Cost $15,100/year (June 2021) for one child divided by number of school days in a year- 180 day/year (2018) = $15,100/180 = $83.89 (A). Assumption based on an 8-hour day.
Source: American Progress. "The True Cost of High-quality Child Care Across the United States," June 28, 2021, https://www.americanprogress.org/issues/early-childhood/reports/2021/06/28/501067/true-cost-high-quality-child-care-across-united-states/.
Source: National Center for Education Statistics. "Number of instructional days and hours in the school year, by state," 2018, https://nces.ed.gov/programs/statereform/tab5_14.asp.
** Input from survey responses.
*** 90% confidence intervals in parentheses.

A.2 Connecticut X1942B Cross-Cutting NEI Study – Residential HP & HPWH NEIs (2023)

A.2.1 Non-Health NEIs

The total dollar value of all non-health related NEIs is $446 and $220 for the average heat pump and HPWH program average participant, respectively. Figure 5 shows the total dollar value of all NEIs per year by heat pump type for program participants who received incentives for heat pumps and/or HPWHs. While GSHPs have the highest overall NEI values of all the measures ($647), the value is based on responses from only six participants (note the wide range of the 90% confidence interval in Figure 16). CASHPs, with 12 respondents, have similarly wide confidence intervals. HPWHs, have the lowest overall NEI value at $220. The differences in the total dollar value of the NEIs by heat pump type are not statistically significant.

Figure 16: Annual NEI Dollar Value per Participant by Measure*



*Bars show 90% confidence intervals.

Figure 17 shows the corresponding percent of savings by measure. On average, respondents value NEIs by 104% for heat pumps and 84% for HPWHs when compared to the value of their expected energy savings.

Figure 17: Percent of Savings by Measure*

*Bars show 90% confidence intervals.

Heat pumps only. On average, the NEIs with the highest values are comfort during winter ($88.05), equipment noise ($73.25), comfort during the summer ($69.43), appearance of the home ($61.50), and safety of the home ($54.03). Equipment maintenance, reliability, frequency of fuel deliveries had the lowest values (Table 26).

CASHPs. For individual NEI values reported for CASHPs, comfort during summer and winter have the highest NEI values at $132.75 and $124.05, respectively. CASHP end-users value equipment reliability and maintenance as well as frequency of fuel deliveries the lowest (Table 26).

GSHPs. The NEIs with the highest values are equipment noise, home safety, and the appearance of the home (Table 26). Comfort during summer and comfort during winter have lower NEI values compared to the heat pump only NEI values. This is likely due to the adjustments, made to comfort during summer and winter based on whether installation conditions had pre-existing cooling, full or partial displacement, and/or added new load. A larger share of respondents who installed GSHPs did not have preexisting cooling and/or displaced an old heating or cooling system while adding new load compared to other heat pump types, which contributed to lower values for comfort during summer and winter.[67]

End-users primarily had either central air conditioner or no cooling system prior to installing their CASHPs and GSHP. These respondents also indicated high values for equipment noise and appearance of the home. While it is unlikely that installing a CASHP or GSHP resulted in improvements in noise and appearance over central air conditioning or no cooling system, the study did not ask respondents to explain how the noise or appearance improved. Due to the

[67] Of the six respondents who installed GSHPs, three did not have pre-existing cooling and one displaced their old cooling system while adding new load. Additionally, two displaced their old heating system while adding new load.

smaller sample size of this group, the study recommends using the heat pump only values for CASHPs and GSHPs.

MSHPs. Respondents who installed MSHPs gave the highest values to comfort during winter, equipment noise, comfort during summer, and appearance of the home (Table 26). The higher value for equipment noise for MSHP respondents ($72.13) may be because most respondents (59% of 170 respondents) reported the MSHP served a room that was previously cooled with a window air conditioner (AC) which are typically noisier than MSHPs. Respondents who replaced window, wall, or portable ACs value the reduced equipment noise from MSHPs at $95.45 [n=112; 90% confidence intervals = ($70.38, $120.53)] compared to $27.10 for respondents who had other sources of air conditioning or did not have any previous air conditioning [n=58; 90% confidence intervals = ($3.52, $50.68)]. The differences in these estimates are statistically significant at the 90% confidence level. Similarly for appearance of the home, respondents who replaced a window AC and similar units value appearance higher ($73.90 versus $28.91) that those who did not although the values are not statistically different.

When asked if there were other NEIs experienced with their MSHP installation, 8% of respondents reported reduced humidity and 4% reported not having to install or remove and store the air conditioning unit as NEIs. These NEIs were valued at $10.91.

A.2.2 Health NEIs

Annual NEI values per participant attributable to avoided illnesses range from $0.33 to $7.01 ($3 to $73 lifetime). Table 40 provides the high-level calculation of the annual value per average participant attributable to asthma, allergies, sinusitis, and cold/viruses. The survey yielded very low levels of change in the number of incidences occurring per year. Survey respondents reported low levels of change for the other ailments. The analysis resulted in annual NEI values (per participant) of $7.01 for allergies, $1.98 for sinusitis, and $0.33 for colds and viruses. Asthma is valued at $2.29 but is not statistically significantly different from zero.

Table 40: Annual and Lifetime NEI Values Per Participant for Reduced Illnesses from Heat Pumps

	Asthma	Allergies	Sinusitis	Colds/ Viruses
Avoided cost per incidence, adjusted to 2021 dollars* (A)	$284	$684	$249	$35
Avoided out of pocket cost per incident adjusted for insurance coverages** (B)	$108	$259	$95	$13
Change in number of incidents per year*** (C)	0.021 (-0.004, 0.05)	0.027 (0.01, 0.05)	0.021 (0.004, 0.04)	0.025 (0.01, 0.04)
Annual value per average participant attributable to specific avoided illnesses (B×C)	**$2.29 ($-0.38, $4.96)**	**$7.01 ($2.15, $11.89)**	**$1.98 ($0.40, $3.65)**	**$0.33 ($0.10, $0.56)**
Lifetime NEI attributable to program measures****	**$23.78 ($-3.94, $51.50)**	**$72.73 ($22.30, $123.39)**	**$20.60 ($4.16, $37.90)**	**$3.44 ($1.05, $5.78)**

* Source: Agency for Healthcare Research and Quality. Medical Expenditures Panel Survey, 2021. https://www.meps.ahrq.gov/mepsweb/.
** Avoided out of pocket cost per one incident adjusted for insurance coverages = avoided cost per incidence, adjusted to 2021 dollars × Percent of CT residents uninsured / not covered by health insurance for Northeast × Average percent out of pocket payment (from MEPs). Example Asthma: $284 (A) × 5.9% × 34% = $108 (B)
*** Incidence calculated from survey responses.
**** Lifetime NEI attributable to program measures = Annual value per average participant attributable to avoided illness × weighted average years lifetimes × discount rate. Example Asthma: $2.29 × weighted average years lifetimes × 15 years × 5% = $23.78; 90% confidence intervals in parentheses

Annual NEI value per participant attributable to avoided missed work is $15.18. Table 41 calculates presents the annual value per average participant attributable to missed work. Respondents reported an average of 0.27 fewer missed worked days after installing a heat pump through the program which equates to an annual avoided cost of $15.18.

Table 41: Annual NEI Values Per Participant for Missed Work

	Missed Work Values
Wages per day for average residential household* (A)	$251.68
Wages lost per day for households with primary earner (corrected for without sick leave)** (B)	$55.37
Change in number of average workdays missed due to program effect (C)***	0.27 (0.15, 0.40)
Changes in household wages from change in sick days lost from work (B×C)******	**$15.18 ($8.16, $22.21)**

* Wages per day for average residential household = Median hourly wage for Connecticut for all occupations in 2020 is $31.46 × Hours per workday = $31.46 × 8 = $251.68 (A)
Source: U.S. Bureau of Labor Statistics. "May 2020 State Occupational Employment and Wage Estimates Connecticut," May 2020, www.bls.gov.
** Wages lost per day for households with primary earner (corrected for without sick leave) = Percent of homes without sick leave in 2020 is 22% × hourly wage for average residential household. $251.68 (A) × 22% = $55.37 (B)
Source: U.S. Bureau of Labor Statistics. "Employee Benefits in the United States – March 2021." News Release, September 23, 2021, https://www.bls.gov/news.release/pdf/ebs2.pdf, Table 6 (pg. 17).
*** Input from survey responses.
**** 90% confidence intervals in parentheses.

Annual NEI value per participant attributable to avoided missed school is $2.71. The analysis found a very small (0.03 days) reduction in the average number school days missed, as shown in Table 42, after program participation.

Table 42: Annual NEI Values Per Participant for Missed School

	Missed School Values
Savings from childcare from 1 day of reduced absences* (A)	$83.89
Change in number of average school days missed due to program effects** (B)	0.03 (0.002, 0.06)
Participant value from changes in sick days lost from school (A×B)***	**$2.71 ($0.14, $5.27)**

* Savings from childcare from 1 day of reduced absences = Family Childcare Cost $15,100/year (June 2021) for one child divided by number of school days in a year- 180 day/year (2018) = $15,100/180 = $83.89 (A). Assumption based on an 8-hour day.
Source: American Progress. "The True Cost of High-quality Child Care Across the United States," June 28, 2021, https://www.americanprogress.org/issues/early-childhood/reports/2021/06/28/501067/true-cost-high-quality-child-care-across-united-states/.
Source: National Center for Education Statistics. "Number of instructional days and hours in the school year, by state," 2018, https://nces.ed.gov/programs/statereform/tab5_14.asp.
** Input from survey responses.
*** 90% confidence intervals in parentheses.

A.3 Massachusetts Low-Income Multifamily Health- and Safety-Related NEIs Study (2021)[68]

Below, we provide a brief overview of the monetization of the four NEIs from the Multifamily Health and Safety NEI study.

A.3.1 Thermal Stress

The study used responses to resident survey questions and inputs gleaned from secondary literature[69] to determine annual household savings attributable to reduced medical treatment and avoided deaths due to exposure to extreme temperatures in the home.

Respondents were asked about several healthcare outcomes (doctor's office visit, emergency department visits, and hospitalization) and the report calculated the change in number of visits reported to treat medical conditions associated with exposure to extreme indoor temperatures.

Respondents Awere asked, "During the past 12 months, how many times [because apartment was too cold or too hot] did anyone in the household have to go to… [a doctor, the emergency department, or be hospitalized]?" Post-weatherization, respondents reported fewer incidences of visits to all care settings for cold-related Thermal Stress and fewer hospitalizations and doctor's office visits for heat-related Thermal Stress. Results from independent samples t-tests show that the changes in both emergency department and doctor's office visits for cold-related thermal stress were statistically significant post-weatherization, but hospitalizations were not.

The report conducted regression analyses to control for observable differences between groups and tested robustness of the results by exploring both statistical significance and sensitivity of results to regression model specification. The regression analyses produced statistically significant estimates of change for the same care settings as the independent samples t-tests (doctor's office visits and emergency department visits) for Thermal Stress (Cold).

A reduction in hospital cases or emergency department visits results in a decrease in risk of mortality, which becomes a substantial household benefit when the VSL is included. The report

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[68] Three Cubed and NMR Group. 2021. Low-Income Multifamily Health- and Safety-Related NEIs Study (TXC50). Prepared for the Massachusetts Program Administrators. https://ma-eeac.org/wp-content/uploads/TXC50_LIMF-HS-NEIs-Final-Report_2021.08.12.pdf

[69] The team retrieved costs for treatment for cold- and heat-related illnesses associated with thermal stress from online databases provided by the Department of Health and Human Services (DHHS). These databases are sponsored by the Agency for Healthcare Research and Quality (AHRQ), based on the 2015 MEPS and a collection of databases sponsored by AHRQ and referred to as the HCUP. Data related to incidence rates of treatment type and number of deaths following hospitalizations was mined from both the MEPS and HCUP databases using the International Classification of Diseases diagnostic codes, associated with "Effects of reduced temperature" (ICD-9-CM 991.0-991.9) and "Effects of heat and light" (ICD-9-CM 992.0-992.9) as the queries. Several medical conditions are associated with exposure to extreme temperatures, with hypo- and hyperthermia being the most extreme, and less prevalent.

calculated the value of avoided deaths from reductions in thermal stress using the estimate of change of emergency department visits.

A.3.2 Arthritis

Arthritis prevalence (i.e., respondents self-reporting current arthritis) for the weatherized group for all regions combined was 49%. The report calculated the Arthritis NEI using responses to arthritis-related hospitalization questions asked of the head-of-household in the resident survey. The report calculated difference in means for each type of medical care used to treat arthritis flares (i.e., urgent care, emergency department visits, and hospitalizations) using cross-sectional analysis of data from respondents that have been diagnosed with arthritis. The report gathered average cost data for Massachusetts hospitalizations specific to worsening arthritis symptoms from discharge data for all age categories and payer types from the Healthcare Cost and Utilization Project (HCUP). The report gathered medical expenditure data for urgent care from the MEPS for arthritis-related outpatient care and emergency department costs.[70] The report inflated medical costs data for all treatment types to 2020 costs and adjusted them to reflect costs in Massachusetts.

A.3.3 Home Productivity

Home Productivity was quantified based on responses to the resident survey question related to number of days of poor sleep and inputs identified in the secondary literature, such as annual productivity increases attributable to better sleep and rest, to determine annual household savings attributable to increases in annual non-market household production (i.e., housework) due to better sleep and rest. Existing literature posits that lack of sleep can have an adverse impact on productivity. The report’s findings indicate that there are reductions in reports of poor sleep from respondents that are weatherization recipients. The report also found that levels of outdoor noise and disturbance from outdoor noise, which can contribute to poor sleep and negative health outcomes, were lower wfor the Comparison-with-Treatment group.

A.3.4 Reduced Risk of Fire

Home fires are relatively rare; therefore, reduced fire risk is difficult to capture through self-reported surveys. Larger sample sizes than the ones in this study would be needed to properly measure fire incidence. The report used inputs mined from secondary literature to estimate annual household savings attributable to reduced medical treatment and avoided deaths from

[70] The report determined that it is reasonable to use out-patient claims costs as a proxy for urgent care costs. For example, the urgent care clinic at Mass General Hospital, which treats arthritis flares, codes urgent care charges as “out-patient” claims.

reduced occurrences of home fires. For the Reduced Fire Risk NEI, the report derived the reduced probability of fire (-0.0003) in a MF unit from the reduced probability of fire in a LISF home.[71]

Home fires can be prevented by installing measures that reduce fire risk, thereby reducing property damage and cases of occupant injury and/or death, or by repairing systems or equipment that could ignite fires. Measures shown to have the most impact on fire risk reduction are repairing or replacing faulty central space heating systems and clothes dryer vents; making electrical repairs; adding insulation; and installing or replacing smoke detectors.

A.4 Massachusetts Residential Heat Pump NEIs Study, MA21X21-E-RHPNEI (2023)[72]

A.4.1 Quantifying Indoor Air Quality NEIs

The combustion processes used in fossil fuel furnaces produce multiple byproducts that pose health hazards, such as carbon monoxide (CO) and nitrogen dioxide (NO2). When not properly vented, these harmful chemicals can infiltrate indoor air and negatively affect occupant health.

Carbon Monoxide Poisoning

While rare, operator errors, lack of maintenance, or equipment malfunctions can cause carbon monoxide (CO) from furnaces to build up inside a residence and lead to CO poisoning and, in extreme cases, death. Combustion of fossil fuels is known to produce multiple pollutants, including carbon monoxide. In a furnace with properly fitted ventilation, CO is safely exhausted to the outdoors. The study estimated the number of unintentional, non-fire-related CO deaths that could be prevented by removing combustion furnaces (i.e., fully displacing them with heat pumps) from homes and the resulting benefit based on the federally established Value of a Statistical Life (VSL). The monetized value for this NEI is $0.34 per home, per year.

Respiratory Illness due to Nitrogen Dioxide Exposure

Older models of natural gas furnaces often have continuously burning pilot lights that emit high levels of combustion byproducts, including nitrogen dioxide (NO2).[73] Data collected from 352 U.S. homes showed that NO2 levels reached 18-22 ppb in homes with natural gas furnace pilot lights

[71] Three3 and NMR. 2016. Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts Study. Submitted to Massachusetts Program Administrators. https://ma-eeac.org/wp-content/uploads/Low-Income-Single-Family-Health-and-Safety-Related-Non-Energy-Impacts-Study.pdf

[72] NMR Group, Three Cubed, and DNV. 2023. Residential Heat Pump NEIs Study (MA21X21-E-RHPNEI). Prepared for the Massachusetts Program Administrators. https://ma-eeac.org/wp-content/uploads/MA21X21-E-RHPNEI_Residential-Heat-Pump-NEIs-Study-Final-Report_2023.07.21.pdf

[73] Mullen, N. A., Li, J., Russell, M. L., Spears, M., Less, B. D., & Singer, B. C. (2015). Results of the California Healthy Homes Indoor Air Quality Study of 2011-2013: Impact of Natural Gas Appliances on Air Pollutant Concentrations. Indoor Air, 26(2), 231–245. https://doi.org/10.1111/ina.12190

and 32-58 ppb in homes that additionally had a natural gas cooktop (with higher measurements found in kitchens). Homes with natural gas cooktops but no furnace pilot lights recorded NO2 levels of 12-41 ppb, depending on where the measurements were taken and whether the cooktop had a pilot light. By comparison, homes with electric cooktops and no pilot lights saw only 6.0-6.5 ppb NO2. A separate study (Garrett, et al., 1998) found that living in a home with NO2 levels exceeding 10 ppb was associated with a substantially higher risk (Odds Ratio (OR) = 3.62) of respiratory illness symptoms for children compared to homes with NO2 levels under 5.3 ppb. Accordingly, the study estimated the benefits of removing furnaces with pilot lights (i.e., fully displacing them with heat pumps), but only for homes with non-gas cooktops as homes with natural gas cooktops would continue to have NO2 levels above the threshold for health impacts even after the furnace pilot light was removed. The monetized value for this NEI is $14.14 per home, per year. The Team notes that the prevalence of pilot lights, and therefore the value of this NEI, will decrease over time as more homes buy new furnaces without pilot lights.

A.4.2 Quantifying Thermal Stress NEIs

The evidence found from the literature review focused primarily on thermal stress impacts related to hot weather, large same-day temperature swings, and heat waves. The evidence highlights the importance of cooling strategies in reducing health risks and outcomes. The evidence base suggests that adverse health impacts occur when outdoor temperatures are high. Some sources indicate that heat-related morbidity and mortality risks rise on summer days when temperatures increase by 10 degrees Fahrenheit over the mean apparent temperature.[74] These risks can be higher for certain demographics, such as for people over 65 years old. The results presented below are for three potential thermal stress-related NEIs: heat-related mortality, heat-related morbidities, and improved productivity gains from avoided cognitive impacts due to extreme heat. These NEIs are specifically attributed to homes that added cooling but would not have had cooling if not for installing a MA PA-supported heat pump.

Heat Related Mortality

Several studies have shown strong evidence of a decrease in heat related mortality risks over the last few decades that are attributable to specific interventions and strategies.[75,76] The use of air conditioning is one of the most straightforward strategies to reduce negative health impacts from heat stress. Various studies have evaluated the role of air conditioning in modifying the risks

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[74] Ostro, B., Rauch, S., Green, R., Malig, B., & Basu, R. (2010) The effects of temperature and use of air conditioning on hospitalizations. *American Journal Of Epidemiology*, 172(9), 1053–1061. https://doi.org/10.1093/aje/kwq231

[75] Arbuthnott K, Hajat S, Heaviside C, Vardoulakis S. Changes in population susceptibility to heat and cold over time: assessing adaptation to climate change. *Environmental Health* 2016;15(1):S33.

[76] Kinney PL. Temporal Trends in Heat-Related Mortality: Implications for Future Projections. *Atmosphere* 2018;9(10):409

associated with mortality events related to exposure to high temperatures using several individual and aggregated-level study designs.[77,78,79] Heat stress deaths are caused directly by heat illnesses such as heat exhaustion and hyperthermia, and heat-exacerbated deaths happen when heat worsens existing chronic conditions such diabetes or heart disease.

The Team leveraged data from the state of New York on the annual estimates of heat-related mortality events collected during the months of May through September from 2010 to 2019, then applied the rate of heat-related mortality in the population of New York to the population of Massachusetts to estimate the number of heat-related mortalities that occur annually in Massachusetts. Results from another study show an independent association between increased air conditioning prevalence and reduced heat-related mortality risk.[80] Excess deaths due to heat decreased during the study periods from 1.70% to 0.53% in the U.S.[81] Increased air conditioning explained 16.7% of the observed decrease. Accordingly, the study developed an algorithm that monetizes the benefits of different prevalence rates of adding air conditioning to homes that would not have had cooling if not for installing a PA-supported heat pump. The approach estimates the number of heat-related deaths due to lack of air conditioning in homes and the resulting risks and benefits based on the literature review and the federally established VSL.

For each heat pump type, the Team assigned values based on non-cooling baseline values, i.e., the percentage of participants that would not have installed cooling without the PA-supported heat pump). This NEI would only apply if the heat pump meets at least 50% of the overall cooling load of a home that had no pre-existing cooling.

The Team believes that it is safe to assume that 100% of central heat pump installations would meet at least 50% of the home's overall cooling load. In order to determine the percentage of mini-split heat pump installations with added cooling that would meet at least 50% of the home's cooling needs, the Team analyzed the data from the customer surveys conducted as part of the

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[77] Anderson BG, Bell ML. Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiology* 2009;20(2):205.

[78] Barreca A, Clay K, Deschenes O, Greenstone M, Shapiro JS. Adapting to climate change: The remarkable decline in the US temperature–mortality relationship over the twentieth century. *Journal of Political Economy* 2016;124(1):105-159.

[79] Bobb JF, Peng RD, Bell ML, Dominici F. Heat-related mortality and adaptation to heat in the United States. *Environmental Health Perspectives* 2014;122(8):811-816

[80] Sera, F., Hashizume, M., Honda, Y., Lavigne, E., Schwartz, J., Zanobetti, A., Tobias, A., Iñiguez, C., Vicedo-Cabrera, A. M., Blangiardo, M., Armstrong, B., & Gasparrini, A. (2020). Air Conditioning and Heat-related Mortality: A Multi-country Longitudinal Study. Epidemiology (Cambridge, Mass.), 31(6), 779–787. https://doi.org/10.1097/EDE.0000000000001241

[81] Ibid.

ongoing Mass Save Heat Pump Metering Study (MA22R51-B-HPMS).[82] These customer surveys collected detailed data on the spaces in the home that are served by the heat pump the respondent installed. In order to convert the spaces in the home served by the heat pumps to a percentage of square footage of the home, the Team incorporated external data from the NAHB/Wells Fargo Housing Market Index survey[83] to assign a percentage to each space cooled and then calculate the percent of the overall home that is cooled by the heat pump. The analysis showed that 74% of mini-split heat pump installations would meet at least 50% of the home's overall cooling load.

The Team recommended applying the heat-related mortality risk NEI to non-cooling baseline scenarios. A limitation of this approach is that it captures the presence of air conditioning equipment in the home but does not capture its actual use for cooling. It is also possible that some mini-split HP installations added 50% or more new cooling to a home with less than 50% of the home cooled previously (e.g., a home that went from 30% cooled with pre-existing cooling equipment to 80% or more cooled with heat pumps). The Team could not determine how much new cooling a mini-split heat pump installation added to a home with pre-existing cooling because the customer surveys from the Mass Save Heat Pump Metering Study did not collect any data on the parts of the home that was cooled prior to heat pump installation. Therefore, the Team makes a conservative assumption that the NEI for Heat-Related Mortality Risk is zero for homes in which heat pumps displace or supplement existing cooling equipment and recommends applying the NEI only to homes with no pre-existing cooling.

Reduced Cognitive Impacts from Extreme Heat

Observations in the evidence base suggest that impacts from high indoor temperatures during hot weather can impact cognitive functioning, even in younger, healthy populations. The evidence suggests that when indoor temperatures are below 27 degrees Celsius (80.6 degrees Fahrenheit) improvements in general health and wellbeing are observed.[84] The presence of air conditioning can reduce negative impacts on cognitive function, such as concentration and productivity, that

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[82] Guidehouse provided the raw data for the customer surveys, which were conducted in two waves.
[83] Spaces in New Homes: NAHB/Wells Fargo Housing Market Index Survey, November 2018. https://www.nahb.org/-/media/224EC507D1B94735B1BDBC6C39B1E8E6.ashx
The NAHB/Wells Fargo Housing Market Index survey is a monthly survey of NAHB members designed to understand the single-family housing market. The Spaces in New Homes report was based on questions added to the November 2018 monthly survey that asked builders to estimate, for a typical new home, the total square footage of the home and the percentage of the total square footage of the home allocated to individual rooms of the home.
[84] Cedeño Laurent JG, Williams A, Oulhote Y, Zanobetti A, Allen JG, Spengler JD (2018) Reduced cognitive function during a heat wave among residents of non-air-conditioned buildings: An observational study of young adults in the summer of 2016. PLoS Med 15(7): e1002605. https://doi.org/10.1371/journthal.pmed.1002605

occur from high indoor temperatures during heat waves.[85] Cognitive performance decreased linearly with an increase in indoor temperature exposure, indicating impacts on educational attainment, economic productivity, and workplace safety.[86] The study estimated the impacts of reducing negative impacts on cognitive function due to the presence of air conditioning for individuals that work from home. The estimate only considers homes that have added cooling due to the heat pump installation but would not have otherwise.

Similar to the Heat-Related Mortality Risk NEI, the Team made a conservative assumption that the NEI for Reduced Cognitive Impacts from Extreme Heat is zero for homes in which heat pumps displace or supplement existing cooling equipment. Therefore, the NEI applies only to homes with no pre-existing cooling. The Team used the same finding from the analysis of the customer survey data from Mass Save Heat Pump Metering Study that 74% of mini-split heat pump installations meet at least 50% of the home's overall cooling load.

It should be noted that given projections of an increase in the number of extremely hot days and heat wave occurrences in Massachusetts, the PAs should consider updating this NEI regularly using the previous year's number of days over 90 degrees Fahrenheit.[87] In Iaddition, the employment statistics (i.e., working from home; percentage of home with at least one employed person, etc.), the percentage of homes with non-cooled baseline, as well as the percentage of heat pump installations that meet at least 50% of the cooling load of a home may change over time, so the study team recommended regular updates to this NEI.

Heat Related Morbidities

The study did not recommend monetizing heat-related morbidity (health risk) NEIs due to uncertainty in chaining the results from the limited evidence base to Massachusetts.

The Team found fewer articles that have studied the effects of temperature on morbidities, especially hospitalization.[88] According to a recent report of the Intergovernmental Panel on Climate Change, global temperatures are expected to increase in the future, with more frequent and severe heat waves. The recently released Massachusetts Climate Change Assessment similarly projects that Massachusetts summers will be warmer in the future with more heat waves and far

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[85] Ibid.
[86] Ibid.
[87] https://www.mass.gov/info-details/massachusetts-climate-change-assessment
[88] Schwartz J, Samet JM, Patz JA. Hospital admissions for heart disease: the effects of temperature and humidity, *Epidemiology*, 2004, vol. 15 6 (pg. 755-761)

more days over 90 degrees Fahrenheit.[89] Therefore, it is important to obtain a better understanding of heat-associated morbidities. In addition, relatively little is known about the effectiveness of mitigation strategies, such as use of air conditioners, in reducing non-fatal health impacts from extreme heat events. Studies on the effects of actual air conditioner use on temperature-related health outcomes are limited. The effects of air conditioning may be confounded by other regional characteristics, such as demographic and economic factors.[90] As a result, there is a need for more localized estimates of the effects of temperature on morbidity and on the effectiveness of air conditioning use in mitigating these effects.

A.4.3 Quantifying Fire Risk NEIs

The study used data from the National Fire Incident Reporting System and Medical Expenditure Panel Survey (MEPS) to estimate NEIs for avoided home fires (and avoided building losses and civilian casualties).

Overall, replacing furnace and boilers with heat pumps will yield a small NEI for avoided home fires. For example, replacing a fossil fuel furnace with a heat pump will result in an NEI value of three cents.

[89] Intergovernmental Panel on Climate Change, *Assessment Report 6 Synthesis Report: Climate Change 2023.* Geneva, Switzerland Intergovernmental Panel on Climate Change (http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf). (Accessed February 6, 2023)
Massachusetts Climate Change Assessment. 2022. https://www.mass.gov/info-details/massachusetts-climate-change-assessment

[90] Chung Y, Yang D, Gasparrini A, Vicedo-Cabrera AM, Fook Sheng Ng C, Kim Y, Honda Y, Hashizume M. Changing Susceptibility to Non-Optimum Temperatures in Japan, 1972-2012: The Role of Climate, Demographic, and Socioeconomic Factors. *Environ Health Perspect* 2018;126(5):057002.