


Low-Income Multifamily Health- and Safety-Related NEIs Study (TXC50)

FINAL REPORT

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SUBMITTED TO:
Massachusetts Program Administrators

SUBMITTED BY:
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Low-Income Multifamily Health- and Safety-Related NEIs

Coordinating with a multi-state evaluation funded through grants awarded by The JPB Foundation, this study quantified and monetized health- and safety-related non-energy impacts (NEIs) attributable to improvements in the energy efficiency of multifamily buildings served through the Mass Save income-eligible coordinated delivery initiative.

Approach

- Quasi-experimental pretest-posttest design to estimate the causal non-energy impacts of weatherization on low-income households without random assignment. Administered surveys to 3 groups of residents:

Weatherized during the study	Not weatherized	Already weatherized
Treatment (T)	**Control (C)**	**Comparison (CwT)**

- Identified NEIs with results from statistical analysis or other supporting evidence strong enough to recommend the Massachusetts PAs claim them.
- Produced unadjusted NEI estimates by running simple difference in means tests. For NEIs meeting threshold for statistical significance, produced regression-adjusted estimates to control for differences between study groups and test statistical rigor of estimate.

Key Findings

Four of the NEIs – Arthritis, Thermal Stress (Cold), Home Productivity, and Reduced Fire Risk – met the adoption criteria.

Recommended NEIs Per Housing Unit Per Year

Arthritis	Thermal Stress (Cold)	Home Productivity	Reduced Fire Risk	=	Total per Weatherized Household
$49	$1,426	$49	$13		$1,537

Recommended Percent Attribution of NEI Values by Measure

Air Sealing: 24% **Insulation: 24%** **Heating: 52%**

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Acronyms

Acronym	Definition
ASHP	Air-source heat pumps
C	Control
CAP	Community Action Program
CARE	Center for Applied Research and Evaluation
CDC	Centers for Disease Control and Prevention
CHIA	Center for Health Information and Analysis
CO	Carbon Monoxide
CS	Cross-sectional
CVD	Cardiovascular Disease
CWL	Control on Waiting List
CwT	Comparison-with-Treatment
DID	Difference-in-Differences
DOE	Department of Energy
DOT	Department of Transportation
DV	Dependent Variable
ED	Emergency department
EPA	Environmental Protection Agency
HCUP	Healthcare Cost and Utilization Project
HH, HHs	Household, Households
Per HH	Per household (i.e., apartment unit)
HHS	U.S. Department of Health and Human Services
HPC	Health Policy Commission
IAQ	Indoor air quality
IM-DCF	Installed Measures Data Collection Form
LIMF	Low-income multifamily
LISF	Low-income single-family
MEPS	Medical Expenditure Panel Survey
MF	Multifamily
MSA	Metropolitan-statistical area
NCHS	National Center for Health Statistics
NEI	Non-energy impact
NEWHAB	Network for Energy, Water and Health for Affordable Buildings
NPC	Non-Program Control
OOP	Out-of-pocket
PAs	Program Administrators
PM	Property Manager
RES38	RES38 Income-Eligible Process Evaluation
S	Societal
SF	Single-family
T	Treatment
VSL	Value of statistical life
WAP	Weatherization Assistance Program
Wx	Weatherized

Executive Summary

Purpose and Objectives

This report presents final results from the Low-Income Multifamily Health- and Safety-Related Non-Energy Impacts (NEIs) Study, conducted for the Massachusetts energy-efficiency Program Administrators (Berkshire Gas, Cape Light Compact, Eversource, Liberty Utilities, National Grid, and Unitil) by Three³, Inc., and NMR Group, Inc., (the evaluation team or "the team") as part of the Special and Cross-Cutting NEIs contract. The team conducted this research in conjunction with a multi-state evaluation that was funded through a grant awarded by the JPB Foundation (the JPB study).

The non-energy impacts presented in this study are changes to resident health and safety, and reductions in participating households' costs other than energy, that result directly or indirectly from weatherization. For example, improvements to housing quality through weatherization can reduce the risks of extreme temperatures in dwellings, or indoor "thermal stress," and of fluctuations in relative humidity that can affect the severity of arthritis sufferers. Improvements such as these can result in NEIs, such as avoiding medical visits and associated health care costs.

Research Objective

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. Monetization entails 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 issues and household budgets resulting from weatherization. For ease of reading, this report refers to the population that is the focus of study as *low-income* (LI) households living in *multifamily* (MF) buildings, or *LIMF*.

This study explored and attempted to monetize a total of 13 NEIs, and to identify which, if any, of the NEIs yielded strong enough results from statistical analysis or other supporting evidence to recommend the Massachusetts Program Administrators (PAs) claim them when screening programs for cost-effectiveness.

Research Methodology

This study collected data from weatherization program participants and non-participants in Massachusetts, while the JPB study collected similar data 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 LI households without random assignment. Using a pretest-posttest design, the two studies administered the same set of survey instruments to three groups of residents of affordable MF buildings before and after a subset of the buildings was weatherized. The studies supplemented these surveys with information about the mechanical and ventilation systems in the buildings before weatherization and the measures installed during weatherization, as reported by participating partners. This study leveraged the data collected by the JPB study to increase the statistical power and precision of the Massachusetts results at no additional cost to the Massachusetts PAs.

Both studies recruited research participants from among residents of affordable MF buildings that fell into the three groups: 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.

The team fielded the surveys for this study from January 2018 through May 2019 (pre-weatherization) and from July 2019 through March 2020 (post-weatherization). Table 1 presents the final sample sizes for both studies by number of sites (each of which may comprise multiple buildings) and dwelling units in each sample.

Table 1: Final Sample Sizes by Study Group

	All Groups Combined	CwT	T	C
	Sample Size (n)			
Total Number of Households	**1,921**	**612**	**417[1]**	**892**
MA Sample	461	206	82	173
Other States	1,460	406	335	719
Total Number of Sites	**186**	**72**	**50**	**64**
MA Sample	60	27	10	23
Other States	126	45	40	41

[1] Treatment group households completed both pre- and post-weatherization surveys (MA and “Other States” combined) = 198

Comparability of Study Groups

The convenience sampling approach limited the ability to recruit study participants who were comparable in all aspects. The team compared the three study groups and the Massachusetts sample with the sample of states from the JPB study to assess differences among them. Key observations from this comparison include the following:

- Respondents from Massachusetts and the other states reside in similar housing types. Slightly more than 50% of respondents in both geographic groups lived in buildings with 40+ units. The majority of respondents in both groups resided in low-rise (<5 stories) buildings. The Massachusetts group had higher rates of publicly owned buildings than the JPB group (40% MA versus 18% JPB), while the majority of buildings in the JPB group were owned by non-profits or privately (73% JPB versus 17% MA). [1]
- There were statistically significant demographic differences between the Treatment, Control, and Comparison-with-Treatment sample groups, and between the Massachusetts sample and the JPB study sample from other states. Across study groups,

[1] Type of ownership was reported as “unknown” for 44% of buildings in Massachusetts.

Massachusetts respondents were older (by a mean of seven years) than respondents in the JPB sample, and had a 16% higher rate of both retirees and single-person households. Of all the demographic characteristics, the racial composition between Massachusetts and the JPB sample is the most dissimilar. The Massachusetts sample had close to twice the rate of White respondents as the JPB sample (71% versus 40%) and less than half the rate of Black or African-American respondents (14% versus 36%). Compared to the Treatment and Comparison-with-Treatment study groups, the proportion of Black or African-American respondents was higher in the Control group: half of the Control group identified as Black or African American compared to less than one-quarter of each the Comparison-with-Treatment and Treatment groups.

We conducted regression analysis to assess the possibility of demographic differences among the study groups affecting weatherization outcomes and control for observable differences.

NEIs Examined

This study attempted to monetize a total of 13 NEIs and to identify which, if any, of the NEIs yielded strong enough results from statistical analysis or other supporting evidence to recommend the Massachusetts PAs claim them. The 13 NEIs the study examined are listed below in alphabetical order:

- Arthritis
- Asthma
- Food Assistance
- Food Spoilage
- Home Productivity
- Low-Birth-Weight Infants
- Missed Days of Work
- Prescription Adherence
- Reduced Fire Risk
- Short-Term, High-Interest Loans
- Thermal Stress (from both excessive heat and cold)
- Trips and Falls
- Work Productivity

The evaluation team explored monetizing these NEIs for the following reasons:

- It was possible and reasonable to obtain the primary data needed to measure and monetize the outcomes from each NEI.
- The team could acquire objective secondary cost data for medical encounters needed for monetization.
- The benefits expected from these NEIs would begin almost immediately, allowing households to see differences due to weatherization before the completion of this research.

Key Findings and Results

Four of the NEIs this study explored – Arthritis, Thermal Stress (Cold), Home Productivity, and Reduced Fire Risk – met the adoption criteria that were set in advance:

- The NEI accrues at the household level, which is the level at which the PAs are currently able to claim NEIs.
- The NEI is not derived from energy bill savings and so do not risk double-counting.
- For NEIs that rely on primary data, both the results of the difference in means analysis (unadjusted estimate) and the coefficient of the weatherization variable in the regression model (regression-adjusted estimate) are statistically significant at p-value <.10 for the outcome of interest. For the one NEI that relies on secondary data only (Reduced Fire Risk), there is sufficient incidence rate and risk factor data from secondary sources to monetize the NEI from these sources.

The team calculated reduced Thermal Stress from cold and Reduced Fire Risk with and without the benefit of avoided deaths (Value of Statistical Life or VSL). The team used the most recent VSL value recommended by the U.S. Department of Transportation (2016) to monetize this benefit.

Recommendations

The Arthritis, Thermal Stress (Cold), Home Productivity, and Reduced Fire Risk NEIs meet all criteria. The team recommends that the PAs adopt the monetized value of these four LIMF health-and-safety-related NEIs. The annual values for each NEI are Arthritis, $49; Thermal Stress (Cold), $1,426; Home Productivity, $49; and Reduced Fire Risk, $13. The total annual value of the recommended household NEI values per unit, excluding societal benefits, is $1,537 (Table 2).

Table 2: Estimated Annual Values for Recommended NEIs Per Housing Unit, with 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**

There is no established methodology by which to attribute NEI values to relevant measures in the BCR models. This study attempted to improve on a previous Massachusetts LI NEI study's approach to attributing NEI values to measures in the BCR models. It developed a simple and empirically-grounded approach using regression analyses and composite NEI values to allocate the recommended NEI values to relevant measures in the BCR models according to each measure's contribution to the change in the composite NEI value. Based on the results of the analysis, the value of each of the recommended NEIs should be allocated across three measures, as follows:

- Air sealing: 24%
- Insulation: 24%
- Heating system upgrades: 52%

For example, the annual total value of recommended NEIs per weatherized housing unit, $1,537, should be allocated across these measures, as follows:

- Air sealing: $369
- Insulation: $369
- Heating system upgrades: $799

CONSIDERATIONS

The team identified lessons from this study that could improve the PAs' future NEI research.

1. When planning future studies of this type, PAs and their evaluators should focus on a narrower range of NEIs. Examining a narrower range of NEIs such as these would mean a shorter survey. The lower response burden would likely result in higher response rates. Another way to boost group sizes is to supplement the current dataset with new data on a narrower range of NEIs, and reanalyze it to yield more definitive results for the selected NEIs.
2. When planning future studies of thermal stress-related NEIs, evaluators should consider using changes in hospitalizations, as well as emergency department visits, to establish the avoided death benefit.
3. In undertaking future studies of this type, PAs and evaluators should be mindful that planning for – and achieving – larger Treatment and Control group sample sizes would increase statistical rigor and the validity of results, especially for NEIs associated with specific chronic illnesses or rare conditions.
4. PAs should ensure that evaluators conducting future studies of MF or SF housing include a household income question in resident surveys.
5. Lack of contact information for property owners/managers and occupants is a substantial impediment to research in the MF rental sector, regardless of the income of occupants. Various steps can be taken in advance of and during research to mitigate this impediment.

   Participating property owners/managers and occupants

   - As part of the program application process, PAs should require – or at least request – that property owners agree in writing to provide access to the building and assist with resident outreach should their building be selected for a PA-sponsored evaluation.

   Non-participating (control group) property owners/managers and occupants

   - Evaluators should develop a sample frame of non-participating rental property owners/managers and occupants of rental properties.

- Evaluators, in combination with PA evaluation, should identify and explore opportunities to work with associations or organizations that house data of affordable multifamily buildings in the state or region of interest, in hopes of leveraging these organizations' data.
- In the near future, the Massachusetts Office of Energy and Environmental Affairs may implement an initiative that includes collecting energy usage data at a municipal or county level. This data will help identify affordable MF properties with high energy usage.

All occupants

- Evaluators should ensure that future research among occupants of MF rental property include budget for in-person canvassing, especially when resident information is unavailable.

6. Be aware of the challenge of establishing building eligibility, group assignment, and measures installed, and prepare for it in advance if possible.
   - PAs should encourage a broader range of low-income stakeholders to become involved in study planning as early as possible to increase the likelihood of obtaining data for participating and non-participating buildings and households.
   - PAs should encourage weatherization agencies and vendors to track participation data more comprehensively, regardless of whether or not jurisdictions outside of Massachusetts are involved.
   - Studies of the MF sector in Massachusetts could be helped by modifying program tracking systems to track participation by facility, not by building, and include the number of units per building.
7. When conducting future studies of this type, evaluators should consider recruiting housing units directly, rather than – or in addition to – recruiting MF buildings first.
8. This study benefited greatly from peer review during the planning process and in the penultimate draft. PAs should consider requiring evaluators to plan for and undertake this practice in future NEI studies.

Key Limitations and Sources of Uncertainty

There are four limitations and potential sources of uncertainty in this study: (1) the possibility of systematic error due to respondents' inaccurate or incomplete recall of past events or experiences (recall bias); (2) a lack of random assignment to Treatment and Control groups, which decreased the likelihood of finding matching groups of buildings and study participants in each sample; (3) bias due to the characteristics of sampled buildings not perfectly representing the population of buildings of interest; and (4) smaller sample sizes than expected, particularly for Treatment buildings, which reduced the power of the analysis.

Section 1 Introduction

This report presents final results from the Low-Income Multifamily Health- and Safety-Related Non-Energy Impacts Study, conducted for the Massachusetts energy-efficiency Program Administrators (PAs)[2] by the evaluation team of Three[3], Inc., and NMR Group, Inc., ("the team" or "we") as part of the Special and Cross-Cutting Non-Energy Impacts contract. The team conducted this research in conjunction with a multi-state evaluation managed by Three[3] and Slipstream, Inc. that was funded through a grant awarded by the JPB Foundation (JPB).

1.1 Research Objective

The objective of this study was to quantify and monetize the health- and safety-related non-energy impacts (NEIs) attributable to improvements in the energy efficiency of multifamily buildings served through the Mass Save® income-eligible coordinated delivery initiative.[3] Monetization entails 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 issues and household budgets resulting from weatherization. For ease of reading, this report refers to the population that is the focus of study as *low-income* (LI) households living in *multifamily* (MF) buildings, or *LIMF*.

1.2 Overview of Non-Energy Impacts

1.2.1 Non-Energy Impacts Framework

In addition to reducing energy consumption, weatherization changes the physical condition of dwellings, potentially resulting in improvements to resident health and safety and reductions in energy costs and other costs. For example, improvements to dwelling quality can reduce exposure to known asthma triggers, such as mold, dust, and extreme temperatures, thus reducing the incidence of acute asthma symptoms. By improving thermal performance, weatherization can reduce the risks of extreme heat or cold in dwellings, or indoor "thermal stress."[4] Improvements such as these can result in NEIs, such as reducing medical costs and lowering the number of days of work lost due to illness.[5] These lowered or avoided expenses can allow households to better afford key items, such as quality food and healthcare, and avoid "heat-or-eat"

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[2] The Massachusetts Program Administrators comprise Berkshire Gas, Cape Light Compact, Eversource, Liberty Utilities, National Grid, and Unitil.

[3] Berkshire Gas, Cape Light Compact, Eversource, Liberty Utilities, National Grid, and Unitil work together as Mass Save to help residents and businesses across Massachusetts save money and energy by providing energy-efficiency programs and services, which helps lead the state to a clean and energy-efficient future.

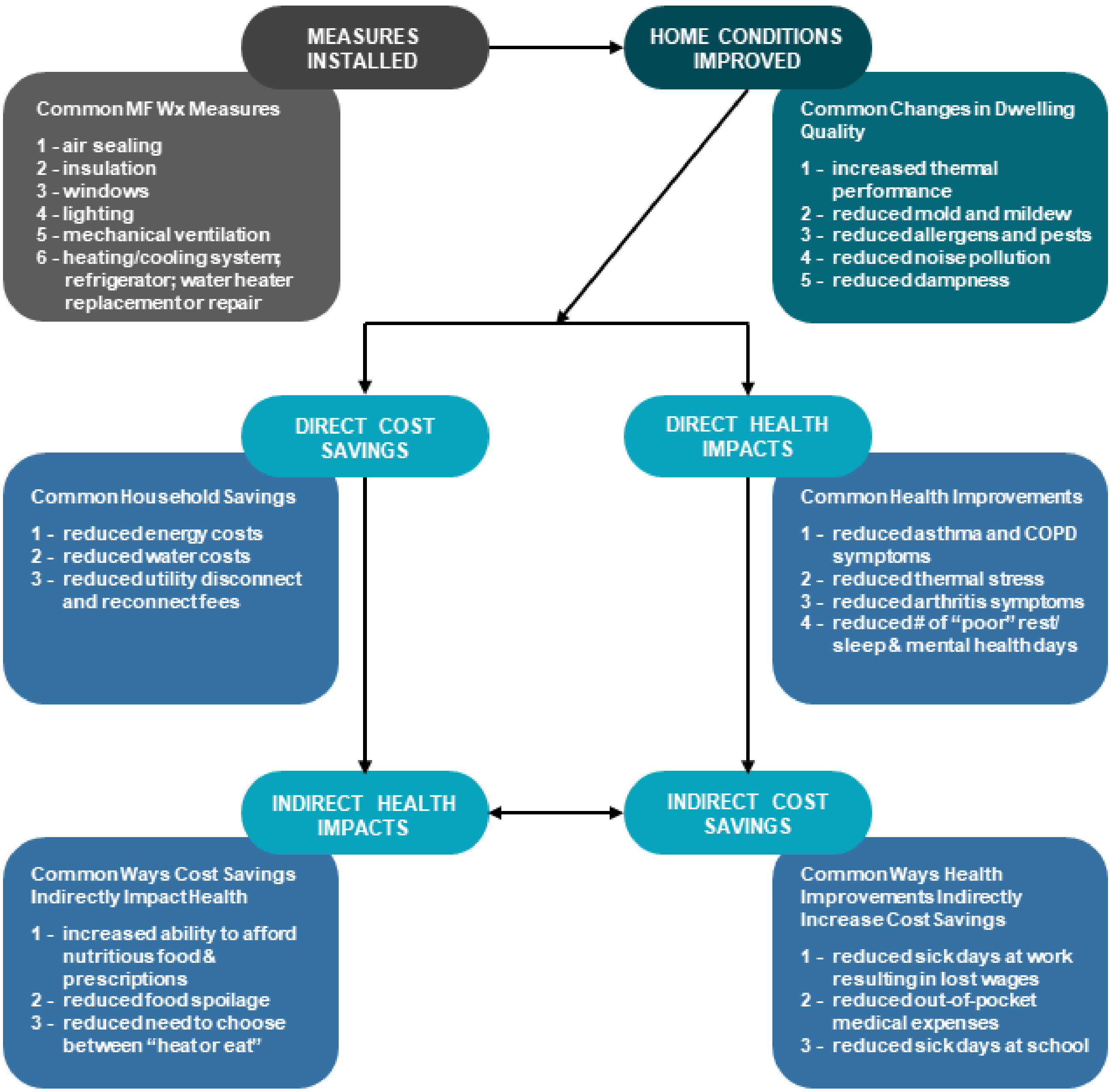
[4] For example, air sealing and insulation decrease drafts and unsafe temperatures inside the home and improve the resilience of homes during extreme weather events.

[5] For example, reduced costs for water and utility disconnect and reconnect fees.

predicaments.[6] These, in turn, can have additional positive impacts on household members' health.

Figure 1 illustrates how weatherizing housing stock can improve household members' health and finances, resulting in a virtuous cycle of positive feedback effects that reinforce and amplify each other.

Figure 1: How Weatherization Can Yield Health Impacts



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[6] Frank et al. "Heat or Eat: The Low Income Home Energy Assistance Program and Nutritional and Health Risks among Children Less Than 3 Years of Age." Pediatrics, Vol. 118, No. 5, November 1, 2006, pp. e1293 -e1302.

1.2.2 NEIs Monetized

This study attempted to monetize a total of 13 NEIs and to identify which, if any, of the NEIs yielded strong enough results from statistical analysis or other supporting evidence to recommend the Massachusetts PAs claim them. We chose these NEIs for monetization for the following reasons:

- It was possible and reasonable for us to obtain the primary data needed to measure and monetize the outcomes from each NEI.
- We could acquire objective secondary cost data for medical encounters needed for the monetization.
- The benefits expected from these NEIs would begin almost immediately, allowing households to see differences due to weatherization before the completion of this research.

Table 3 shows (1) the NEIs we are recommending for adoption and (2) the NEIs that we monetized but are not recommending for adoption. The NEIs we are not recommending are important and substantial, with positive monetizable benefits, but the study did not yield a statistically robust estimate of their monetized values, likely due to insufficient sample size.

The table includes information about the type of NEI (household [HH] or societal [S]) and the potential for double-counting the NEI with energy bill savings. The NEIs the team recommends here for PA adoption have the following characteristics:

- They accrue at the household level, which is the level at which the PAs are currently able to claim NEIs.
- They are not derived from energy bill savings and so do not risk double-counting.
- They either yielded statistically significant results from the regression analysis or there was sufficient incidence rate and risk factor data from secondary sources to monetize the NEIs from these sources.

Table 3: NEIs Monetized in This Study

Monetized NEIs	Type (HH or S)[1]	Derived from Energy Bill Savings (Y/N)
Recommended NEIs		
Arthritis	HH and S	N
Thermal Stress (Cold)	HH and S	N
Reduced Fire Risk	HH and S	N
Home Productivity	HH	N
NEIs Not Recommended for Adoption (due to lack of statistical robustness)		
Asthma	HH and S	N
Missed Days of Work	HH and S	N
Trips and Falls	HH and S	N
Food Spoilage	HH	N
Work Productivity	S	N
Low-Birth-Weight Infants	HH and S	Y (HH)
Short-Term, High-Interest Loans	HH	Y
Food Assistance	S	Y
Prescription Adherence	S	Y

[1] In this and subsequent tables, HH = Household-level NEI; S = Societal-level NEI.

Section 2 Research Methodology

2.1 Research Design and Data Collection

We conducted this Massachusetts-specific NEI study in concert with a larger regional study managed by team member Three[3], referred to here as the JPB study. This study was fielded in a similar time frame as the JPB study and was funded through grants from the JPB. The JPB study collected data from weatherization program participants and non-participants in Illinois, New Hampshire, New York, Pennsylvania, Rhode Island, Vermont, and Wisconsin, while this study only collected data from those in Massachusetts. Both studies took a quasi-experimental approach to estimate the causal NEIs of weatherization on LI households without random assignment. Using a pre-test-post-test design, the two studies administered the same set of survey instruments (the resident surveys) to three groups of residents of affordable MF buildings before and after a subset of the buildings was weatherized. The studies supplemented these surveys with information about the mechanical and ventilation systems in the buildings before weatherization and the measures installed during weatherization, as reported by participating partners. This study leveraged the data collected by the JPB study to increase the statistical power and precision of the Massachusetts results at no additional cost to the Massachusetts PAs.

2.1.1 Resident Survey

Team member Three[3] drafted the resident survey used for both the JPB study and this study. The resident survey was based on the national occupant survey used for the U.S. Department of Energy's Weatherization Assistance Program (WAP) evaluations,[7] but with a number of additions. These included more targeted questions to measure relevant NEIs, such as Asthma, Thermal Stress, and Missed Days of Work, and questions to explore other health, well-being, and safety issues that could be impacted by weatherization, such as Arthritis, Food Spoilage, and injuries from Trips and Falls. Wherever possible, Three[3] drew on existing reputable surveys to develop the new questions.

[7] Three[3] staff designed the occupant survey, managed the national WAP evaluations, and conducted the health and household-related impacts attributable to the WAP study while employed as research staff under the auspices of Oak Ridge National Laboratory.

2.1.2 Study Groups

Both studies recruited research participants from among residents of affordable MF buildings that fell into three groups: 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.

1. Treatment (T): This group comprised buildings that had not been weatherized between March 2008 and the first resident survey, but were scheduled for weatherization within a few months after the first resident survey.[8]
2. Comparison-with-Treatment (CwT): This group comprised buildings that had been weatherized between March 2008 and March 2017.
3. Control (C): This group comprised buildings that had either never been weatherized or that were not weatherized between March 2008 and the completion of data collection.

The baseline (Phase 1) survey measured the dependent variables for participants in each of the three groups. The team administered the second (Phase 2) survey to both the Treatment (ten to 14 months post-weatherization) and the Control (ten to 12 months after the Phase 1 survey) groups to observe any changes in dependent variables. The team only administered the Phase 1 survey to the Comparison-with-Treatment group. (We only used this group as a proxy for post-treatment changes in Phase 1 in order to produce interim results for the PAs and EEAC consultants. For more detail about the study groups, see Appendix E).

2.1.3 Sampling

We conducted a power analysis to set sample size targets for the number of surveys in Massachusetts and the JPB study states. The power analysis relied on two variables: asthma-related emergency department (ED) visits and missed days of work. The team selected these two variables for the power analysis because of all the NEIs measured in the 2016 Massachusetts study of LI Single-Family Health- and Safety-related NEIs,[9] they had the highest values and were among those with the largest effect sizes. We based our estimates of these variables on results from the national evaluation of WAP, using an alpha of 0.1. The team set sample size targets to achieve a confidence level of 90% or higher, with the assumption that the analysis would combine Massachusetts and JPB results. Due to the recruitment challenges described below, we relied on a convenience sampling approach rather than random selection.

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[8] Throughout this report, tables and equations use the acronyms for Treatment (T), Comparison-with-Treatment (CwT), and Control (C).

[9] Three[3] and NMR. "Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts Study." Submitted to *Massachusetts Program Administrators and EEAC Consultants*, 2016. Massachusetts Special and Cross-Cutting Research Area. August 5, 2016 http://ma-eeac.org/wordpress/wp-content/uploads/Low-Income-Single-Family-Health-and-Safety-Related-NonEnergy-Impacts-Study.pdf.

2.1.3.1 Phase 1 Sample Frame

We derived the Massachusetts Treatment sample frame from data provided by the Massachusetts PAs and one Community Action Program (CAP) agency.[10] We obtained the sample frame for other states from numerous lists of eligible buildings provided by state and local agencies, owners of affordable MF buildings, and utilities. The Massachusetts Control sample consisted of (1) projects that had gone through the PAs' or CAP program intake processes were deemed eligible, but were not expected to be weatherized before the start of Phase 2, and (2) LIMF sites in Massachusetts not associated with the Mass Save income-eligible coordinated delivery initiative. (See Appendix E for more details.)

2.1.3.2 Phase 2 Sample Frame

The Treatment and Control respondents from Phase 1 formed the sample pool for Phase 2.

2.1.4 Fielding

We fielded the Phase 1 resident survey from January 2018 through May 2019 and the Phase 2 resident survey from July 2019 through March 2020. We attempted to recruit all respondents to complete the Phase 2 survey at close to the same time of year as they completed the Phase 1 survey (at least within the same season). For the Treatment respondents, this was approximately ten to 12 months after their building was weatherized. For the Control respondents, this was approximately ten to 12 months after they completed their Phase 1 survey. (See Appendix E for more details.)

During Phase 1, we visited 67 eligible sites in Massachusetts and 121 eligible sites in the other states. Each site comprised one or more buildings. We conducted visits in person because the only contact information available was for the property owner/manager of the MF buildings, not for the residents of individual units in each building. During these visits, we also gathered additional contact information to facilitate fielding Phase 2. In-field staff distributed 2,629 survey packets to Massachusetts residents and 5,116 survey packets to residents outside of Massachusetts, for a total of 7,745 surveys. During Phase 2, the team called and/or sent survey packets to 417 households at 50 Treatment sites and 892 households at 64 Control sites. We gave respondents the option of completing the resident survey by telephone or on paper. In Phase 1, we also gave respondents the option of completing the resident survey online.

For households that responded to the Phase 1 survey and provided a phone number, the team called the household to complete the Phase 2 survey. We called each home up to ten times on different days of the week and different times of the day. If the respondent did not answer after ten calls, the phone number was disconnected or otherwise inoperable, or the respondent did not provide a phone number, we mailed a paper survey with an explanatory cover letter, project description, informed consent document, and a $1 bill paper clipped to the cover letter as a gesture of good will and to encourage a response. Upon receiving each completed survey, we mailed the respondent a $40 gift card.

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[10] Action for Boston Community Development (ABCD) provided data on behalf of Eversource, Columbia Gas, and Cape Light Compact (CLC).

By November 2019, it became clear that more than enough Control surveys had been returned for the number of Treatment surveys expected, so the team ceased follow-up efforts for the Control group. From this point, if the team had a phone number for a Control home, the team would still attempt phone calls, but not send a paper survey. When there was no phone number on record, we would send a paper survey but no reminder postcard or second survey. This allowed each home to complete the Phase 2 survey while reallocating resources to increase the Treatment response rate.

Due to a number of factors beyond our control, including lack of availability of contact information for building residents, the need for property management approval for the team to enter the premises to recruit residents for the study, and a lower-than-projected rate of MF building weatherization, the Treatment group from Phase 1 was smaller than anticipated. After observing initially low response rates (15%) for the Treatment group in Phase 2, we sent staff back into the field in November 2019 to distribute survey packets in person. To close the response rate gap between the Treatment and Control groups, in-field staff canvassed a handful of Treatment sites from Phase 1.

Our additional efforts to recruit Phase 2 Treatment group respondents were effective, as the final Phase 2 response rate was 47%. From the Treatment group in Phase 2, the team received 198 household surveys that represented 310 persons (57 from Massachusetts and 253 from other states). Table 4 presents the final sample sizes. Note that in this and subsequent tables, the number of households is always equal to the number of units.

Table 4: Final Sample Sizes by Study Group and Characteristic

	CwT	T		C	
Characteristic	P1 (T_Post)	T_Pre	T_Post	P1	P2
	Sample size (n)				
No. of HHs (Total n=1,921)	612	417	198	892	553
No. of Persons (Total n=2,964)	880	742	310	1,273	699
No. of HHs that completed both pre- & post-weatherization surveys (Total n=751)	0	198		553	
No. of Buildings (Total n = 382)	140	103		139	
No. of Sites (Total n = 186)	72	50		64	

On March 25, 2020, the team suspended all survey efforts due to the COVID-19 pandemic. We determined that any survey results collected after that time would be incomparable with those from Phase 1. We excluded from analysis any incoming surveys that were completed after stay-at-home orders were issued and/or schools were closed in the respondent's state.

2.2 Sample Characteristics

The following sections characterize the samples, discuss comparability between the samples of buildings and respondents, discuss comparability between the Massachusetts sample and the JPB sample, and present data from participating agencies on property characteristics and installed weatherization measures. The resident survey included questions on home livability and dwelling conditions. While we did not use these data to monetize the NEIs, they serve as supporting evidence for monetization.

For additional summary statistics on home conditions of the sample, see Appendix G.

2.2.1 Building Characteristics

Table 5 shows differences in building characteristics among the three study groups from Phases 1 and 2. As the table shows, Treatment and Control building characteristics remained fairly stable from Phase 1 to Phase 2; the Treatment group changed slightly more than the Control group due to the number of buildings excluded from Phase 2 due to the COVID-19 pandemic. (For example, the Treatment group went from 20% to 0% high-rise buildings because these buildings were scheduled for Phase 2 surveys in Spring 2020, when the pandemic halted data collection.[11])

The Comparison group had a larger proportion of both low-rise units (78%) and senior housing units (56%) than either the Treatment or Control groups, and the respondents were more evenly distributed across the participating states. In contrast, 60-64% of the Control group surveys came from Illinois.

[11] This did not affect the validity of results, as the Phase 1 Massachusetts Treatment building sample did not include high-rise buildings.

Table 5: Building Characteristics

(All States Combined)

Building Characteristic		Comparison with Treatment	Treatment		Control	
		P1 (post-Wx)	T_Pre	T_Post	P1	P2
No. of HHs		612	417	198	892	553
Rise						
Low-rise (< 5 stories)		78%	54%	66%	59%	58%
Mid-rise (5 to 9 stories)		16%	24%	33%	34%	37%
High-rise (10+ stories)		5%	20%	0%	6%	6%
Size (housing units)						
5 to 12 units		22%	30%	41%	14%	12%
13 to 39 units		30%	21%	20%	22%	20%
40 or more units		48%	49%	39%	64%	69%
Ownership						
Private		42%	27%	33%	45%	44%
Non-profit and public		54%	51%	57%	33%	35%
Unknown		4%	22%	10%	22%	22%
Housing Function						
Family		14%	26%	17%	22%	19%
Mixed Use		6%	2%	<1%	8%	7%
Senior		56%	12%	17%	30%	27%
Supportive		5%	7%	5%	27%	31%
Unknown		20%	53%	60%	15%	15%
Region/State						
Midwest	Illinois	16%	<1%	<1%	60%	64%
	Wisconsin	11%	8%	6%	5%	5%
Northeast	Vermont	4%	3%	5%	<1%	<1%
	New York	11%	32%	10%	3%	2%
	Rhode Island	11%	31%	47%	8%	7%
	Pennsylvania	12%	1%	0%	5%	3%
	New Hampshire	2%	5%	7%	0%	0%
Massachusetts		34%	20%	25%	19%	20%

Table 6 shows building characteristics of the Massachusetts sample versus the rest of the sample (the "Other States") for each study group. As the table indicates, respondents from Massachusetts and the other states reside in similar types of housing. Similarity in housing characteristics across the sample are important, as systematic differences in key characteristics of buildings can potentially affect the outcomes as much, or more than, systematic differences in demographic characteristics. (Differences in climate zone are also important, which is why the sample frame only included cold-climate-zone states.) Slightly more than 50% of respondents in both geographic groups lived in buildings of 40+ units. The majority of respondents in both groups resided in low-rise (<5 stories) buildings, although at a lower percentage in Massachusetts (62%)

than the JPB group (89%). The high-rise buildings were the least represented in both groups. Ownership of the buildings differed between the Massachusetts and JPB groups. The Massachusetts group had higher rates of publicly owned buildings than the JPB group (40% versus 18%), while the majority of buildings in the JPB group were owned by non-profits or were owned privately (73% versus 17%).[12] The team performed regression analysis to assess whether differences between regions were confounding factors, and found that none were. (See Appendix C for more information.)

Table 6: Building Sample Profile, by MA versus Other States[1]

Building Characteristic	All Groups Combined		Comparison-with-Treatment (P1 Only)		Treatment (T_Pre and T_Post)		Control (P1 and P2)	
	MA	Other States	MA	Other States	MA	Other States	MA	Other States
n (# of units)	**461**	**1,460**	**206**	**406**	**82**	**335**	**173**	**719**
Rise								
Low-rise (< 5 stories)	62%	89%	63%	86%	61%	87%	61%	93%
Mid-rise (5 to 9 stories)	29%	9%	21%	14%	39%	6%	27%	6%
High-rise (10+ stories)	9%	3%	16%	0%	0%	7%	12%	1%
Size (housing units)								
5 to 10 units	17%	19%	9%	24%	34%	22%	8%	10%
11 to 39 units	26%	29%	35%	32%	5%	32%	38%	23%
40 or more units	57%	52%	56%	44%	61%	46%	54%	67%
Housing Function								
Family	2%	44%	3%	23%	2%	79%	0%	30%
Mixed Use	15%	6%	5%	8%	3%	6%	38%	3%
Senior	72%	33%	92%	60%	62%	9%	62%	30%
Supportive	11%	14%	0%	9%	33%	6%	0%	27%
Ownership								
Non-profit	13%	33%	3%	41%	22%	17%	13%	40%
Private	4%	40%	4%	34%	0%	35%	7%	50%
Public	40%	18%	40%	16%	45%	37%	34%	1%
Unknown	44%	10%	53%	9%	33%	11%	46%	9%

[1] Other states include Illinois, Michigan, Wisconsin, New York, Rhode Island, New Hampshire, and Vermont.

[12] Type of ownership was reported as "unknown" for 44% of buildings in Massachusetts.

2.2.2 Respondent Characteristics

The convenience sampling approach described above limited the degree to which strata were fully comparable. As a result, we found statistically significant demographic differences between the Treatment, Control, and Comparison-with-Treatment study groups, and between the Massachusetts sample and the JPB study sample. Table 7 compares demographic characteristics by study group. Demographic differences between the study groups were more frequently statistically significant in Phase 1 than Phase 2. This may be partly due to the larger sample sizes and number of groups in Phase 1 versus Phase 2. The most substantial differences between Phase 1 and Phase 2 were in the Treatment group. For example, in the Treatment group, the proportion of single-person households and respondents without a high school degree both increased 10% from Phase 1 to Phase 2, and the rate of Hispanic or Latino respondents increased by one-third. It seems likely that the loss of high-rise buildings from the Phase 2 data collection due to the COVID-19 pandemic influenced these differences.

Table 7 also shows racial and ethnic imbalances between groups. These differences persisted from Phase 1 to Phase 2. Half of the Control group identified as Black or African American, compared to less than one-quarter each of the Comparison-with-Treatment and Treatment groups.

Numerous previous studies highlight the correlations among socio-economic status, race, and poor health, particularly asthma and arthritis.[13] We conducted regression analysis to assess the possibility of demographic differences among the study groups affecting weatherization outcomes and control for observable differences. We describe the approach to the regression analysis in the next section and present results in Section 3.2, with additional detail in Appendix C.

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[13] For example, Hughes et al. 2016; Forno & Celedon 2009; Asthma and Allergy Foundation of America 2020; Obana & Davis 2016; Greenberg et al. 2013; Riad et al. 2019; Hansen et al. 2013.

Table 7: Survey Respondent Profile, by Group

Respondent Demographics	Comparison-with-Treatment	Treatment		Control	
	P1 (post-Wx)	T_Pre	T_Post	P1	P2
No. of Respondents	**612**	**417**	**198**	**892**	**553**
Age (mean) ***	64	58	60	57	60
Gender (female) (%) **++	70%	69%	73%	62%	60%
Primary Wage Earner Employed (%) *	20%	27%	25%	24%	21%
Primary Wage Earner Retired (%) ***	60%	46%	40%	41%	42%
HH Size (mean) ***+++	1.4	1.8	1.6	1.4	1.3
Single Person HH (%) ***+++	77%	58%	68%	76%	84%
Education (%)					
No High School Diploma **+++	20%	29%	39%	20%	21%
High School Graduate +	38%	32%	35%	37%	37%
Some College	20%	20%	15%	24%	24%
College Graduate +	22%	19%	10%	19%	18%
Race					
White ***	63%	37%	39%	38%	38%
Black or African American ***+++	20%	24%	26%	50%	54%
American Indian or Alaska Native	--	--	<1%	--	2%
Asian ***	6%	2%	2%	1%	<1%
Native Hawaiian or Other Pacific Islander +	<1%	<1%	<1%	<1%	<1%
Hispanic or Latino ***+++	4%	14%	22%	3%	4%
Other ***	4%	13%	7%	6%	4%
Missing ***++	8%	16%	7%	8%	3%**
Do you consider yourself to be of Hispanic or Latino origin? (yes) ***+++	13%	42%	38%	9%	7%

* Difference between all groups is statistically significant at the p<.05 level in Phase 1.
** Difference between all groups is statistically significant at the p<.01 level in Phase 1.
*** Difference between all groups is statistically significant at the p<.001 level in Phase 1.
+ Difference between all groups is statistically significant at the p<.05 level in Phase 2.
++ Difference between all groups is statistically significant at the p<.01 level in Phase 2.
+++ Difference between all groups is statistically significant at the p<.001 level in Phase 2.

Table 8 shows demographic characteristics of respondents from Massachusetts versus those from the states comprising the JPB sample (shown in the table as "Other States"). Across study groups, Massachusetts respondents were older (by a mean of seven years) than respondents in the JPB sample, with a 16% higher rate of both retirees and single-person households. Of all the demographic characteristics, the racial composition between Massachusetts and the JPB sample is the most dissimilar. The Massachusetts sample had close to twice the rate of White respondents as the JPB sample (71% versus 40%) and fewer than half the rate of Black or African-American respondents (14% versus 36%).

Table 8: Survey Respondent Profile, by MA versus Other States[1]

Primary Respondent Characteristics	All Groups Combined		Comparison-with-Treatment (P1 Only)		Treatment (T_Pre and T_Post)		Control (P1 and P2)	
	MA	Other States	MA	Other States	MA	Other States	MA	Other States
n (# of respondents)	**461**	**1,460**	**206**	**406**	**82**	**335**	**173**	**719**
Age (mean)	66	58***	68	62*	65	56***	64	56***
Gender (female) (%)	67%	67%	70%	70%	59%	72%*	71%	60%**
Primary Wage Earner Employed (%)	15%	23%	12%	21%**	11%	28%***	23%	21%
Primary Wage Earner Retired (%)	61%	45%***	65%	57%	61%	41%**	58%	37%***
Single Person HH (%)	82%	66%*	83%	71%*	88%	50%***	76%	76%
Education								
No High School Diploma	24%	23%	23%	19%	30%	29%	19%	20%
High School Graduate	30%	34%	30%	38%*	29%	29%	30%	35%
Some College	20%	20%	20%	18%	22%	17%	19%	24%
College Graduate	21%	17%	23%	19%	12%	18%	28%	15%**
Race								
White	71%	40%***	75%	58%***	65%	31%***	74%	30%***
Black or African American	14%	36%***	12%	23%***	18%	26%	13%	58%***
Asian or American Indian, or Alaskan, Hawaiian, or other Pacific Island Native (Phase 2 only)	4%	4%	6%	8%	0%	2%	5%	3%
Hispanic or Latino	3%	8%	3%	4%	1%	17%***	6%	2%
Other	10%	7%	6%	3%	15%	13%	10%	5%
Missing	10%	11%	8%	8%	12%	16%	9%	8%
Self-identify as Hispanic or Latino Origin? (Yes)	9%	24%**	13%	12%	1%	52%***	13%	8%

[1] Other states include Illinois, Michigan, Wisconsin, New York, Rhode Island, New Hampshire, and Vermont
* Difference between the MA sample and the “Other States” is statistically significant at the p<.05 level.
** Difference between the MA sample and the “Other States” is statistically significant at the p<.01 level.
*** Difference between the MA sample and the “Other States” is statistically significant at the p<.001 level.

2.2.3 Existing Mechanical Systems and Installed Measures

We used the installed measure data to attribute the total value of the monetized NEIs to individual measures for cost benefit analysis. We describe our approach in Section 2.4. Here, we summarize some highlights from the existing systems and installed measure data. See Appendix F for the detailed tables on which this information is based.

Prior to weatherization, 19% of all units did not have a working on-demand mechanical ventilation system. Of those that did have ventilation, more than half (65%) had bathroom fans (which may or may not have vented to the outside) and 22% had a kitchen range hood that vented to the outside.

While 3% of units did not have a working heating system, 30% did not have a cooling system. This difference is reflective of the northern climates in which all buildings were located.

In-unit, hallway/stairwell, and building exterior lighting improvements (e.g., new bulbs and/or fixtures) were the most common set of measures installed, at 84%, 61%, and 61%, respectively. The second most common measure installed in the Comparison-with-Treatment and Treatment subsample was building-level air sealing (55%), followed by heating equipment (52%), new refrigerators (52%), insulation[14] (50%), water-saving devices (47%), domestic hot water (37%), and mechanical ventilation (27%). Cooling equipment and windows were the least common measures installed, at 18% and 14% of buildings, respectively.

Incidental repairs was the most common health and safety measure reported (20%).

2.3 Data Analysis Approach

We used two approaches to estimate the change in rate of incidence of the NEI indicators due to weatherization (the *treatment effect*).

1. We first produced **unadjusted estimates** by running simple difference in means tests using a quasi-experimental study design approach.
2. For those NEI indicators that met the threshold for statistical significance, we then produced regression-**adjusted estimates** using a regression analysis to control for differences in the observable characteristics between the study groups and to test the statistical rigor of the estimate. We recommend using the regression-adjusted estimates for monetizing the NEIs that passed these tests, since the adjusted estimates better control for confounding factors, while the unadjusted estimates do not.

[14] Includes the following insulation types: ceiling, above-grade wall, floor, rim/band joist, and foundation wall insulation.

2.3.1 Unadjusted Estimates

We estimated the unadjusted change in rates of incidence of the NEI indicators using resident survey data. By an "indicator," we mean an outcome related to the NEI of interest that could be attributable to weatherization. We calculated the unadjusted change in incidence using one of two quasi-experimental study design approaches to compare change in outcomes between weatherized and non-weatherized study groups: Cross-sectional (CS) or Difference-in-Differences (DID). We hypothesized that the impacts of weatherization would produce a negative post-treatment rate of incidence for most NEI indicators. A negative value translates to a post-treatment reduction (e.g., fewer medical encounters).

We used a cross-sectional approach (Equation 1), where the Comparison-with-Treatment served as the post-weatherization group and the Treatment and Control groups from Phase 1 were combined to form a pre-weatherization group ($T_{pre}+C_1$).

Equation 1. CS: *Change in incidence (ΔI) =* $I_{CwT} - I_{Tpre+C1}$

In consultation with a Working Group comprising PA staff members and EEAC representatives, we determined that the cross-sectional approach is acceptable when considering NEIs produced by a reduction in "rare events experienced." Specifically, these are events unlikely to strike a household repeatedly over a 12-month period, such as thermal stress-related medical encounters and the birth of a low-weight infant. For NEIs related to "personal needs dependent on circumstances" (e.g., Missed Days of Work, Home Productivity, and Food Spoilage), in consultation with the Working Group, it was also determined that it would be acceptable to use a cross-sectional approach in the absence of sufficient pre- and post-weatherization responses from the Treatment group.

For chronic illnesses, such as Arthritis and Asthma, it is best to measure outcomes experienced by the same household members represented in both the pre- and post-weatherization surveys (i.e., the classic DID analysis using Equation 2 below). For the Arthritis NEI, due to the absence of sufficient Treatment group pre/post responses, obtaining statistical significance through a DID approach was unlikely despite clear evidence of positive outcomes. For this reason, we used a cross-sectional approach to calculate the change in incidence for the Arthritis NEI.

Equation 2. DID: *Change in incidence (ΔI) =* $(I_{Tpost} - I_{Tpre}) - (I_{C2} - I_{C1})$

We performed chi-square and Fisher's exact tests to compare outcomes between categorical or binary variables. We tested for statistical significance of differences in means between groups via an independent samples t-test at a 90% confidence level (corresponding to a p-value <0.1). When conducting a DID analysis, we performed the McNemar test to measure binary outcomes and the non-parametric 2-related samples Wilcoxon signed-rank test to test for statistical significance of differences in means within groups from Phase 1 to Phase 2. We conducted Pearson Chi-square or ANOVA analyses when testing for statistical significance of outcomes calculated by the DID approach.

2.3.2 Regression-Adjusted Estimates

Since we hypothesized that the research outcomes could be affected by regional and demographic differences between the weatherized Comparison-with-Treatment group and the non-weatherized groups (particularly with respect to race and the Midwestern location of most of the control units) and between the two non-weatherized (Treatment and Control) groups, we conducted regression analysis to better control for observable differences. In consultation with the PA and EEAC Working Group, it was agreed that the adoption criterion for NEIs subjected to statistical analysis would be that both the unadjusted and regression-adjusted estimates meet the threshold of statistical significance (p-value<0.10).

We specified a DID regression model as follows:

Equation 3. $Y = \beta_0 + \beta_1 * Wx + \beta_2 * POST + \beta_3 * POST * Wx + \beta_4 * [Covariates] + \epsilon$

Where:

- POST is a dummy variable indicating the post-Wx period
- Wx is a dummy variable indicating whether or not the unit is weatherized
- Covariates are variables included to control for observable differences between the treatment group and comparison group
- β_3 is the difference-in-difference estimate of the treatment effect: the change in Y for treatment group less the change in Y for control group
- ϵ is a "random-error" term

For the CS analysis in the study, there are no pre- and post-Wx observations for the same groups, so we specified the regression model as follows:

Equation 4. $Y = \beta_0 + \beta_1 * Wx + \beta_2 * [Covariates] + \epsilon$

In Equation 4, the key regression coefficient is β_1, which provides the regression-adjusted estimate of the treatment effect attributable to weatherization.

We conducted regression analysis only for the NEIs for which it was feasible and that the PAs could potentially claim: Arthritis, Thermal Stress, Home Productivity (based on improvement in sleep quality), Food Spoilage (based on replacement of an ineffective refrigerator), and Missed Days of Work. This meant that regression analysis was *not* conducted for the following NEIs:

- NEIs with only societal benefits (Work Productivity, Prescription Adherence, Food Assistance), since the PAs cannot currently claim these
- Household NEIs with extremely small sample sizes or an extremely small or zero NEI value (Asthma,[15] Trips and Falls)
- NEIs derived from energy bill savings, because of the potential for double-counting (Short-Term Loans, Low-Birth-Weight Infants, Prescription Adherence, Food Assistance)

[15] The team excluded asthma from the regression analysis because of the combination of the small sample size and the difference in asthma prevalence between the treatment and control group at baseline.

- NEIs drawn from secondary data (Reduced Fire Risk)

In the regression models, we included the following covariates (control variables):

- Region indicator (Midwest) [16]
- Size of building (# of units)
- Respondent age indicator (55+)
- Gender indicator (Male)
- Race indicator (Black/African American)
- Education indicator (HS Diploma/GED or less)

Since the Thermal Stress NEI, with avoided deaths, accounts for the majority of the total value of NEIs being recommended, the team ran additional regression models for Thermal Stress isolating all care settings, with emergency departments visits and hospitalizations being of most interest. These more-urgent care settings are where deaths are most likely to occur. The dependent/outcome variables used in this analysis were as follows:

- Arthritis
  - Number of arthritis pain-related hospitalizations
- Thermal Stress
  - Number of thermal stress – cold-related medical encounters
    - ED and doctor's office visits and hospitalizations
  - Number of thermal stress – heat-related medical encounters
    - ED and doctor's office visits and hospitalizations
- Number of bad days of rest/sleep (Home Productivity)
- Number of times food thrown away due to bad refrigerator (Food Spoilage)
- Number of days primary wage earner missed work due to illness/ injury (Missed Days of Work)

[16] Participating states in the Midwest were Illinois and Wisconsin. Participating states in the Northeast were Vermont, New York, Rhode Island, Pennsylvania, New Hampshire, and Massachusetts.

2.4 Attribution of NEI Values by Measure

Due to the absence of an established methodology to attribute NEI values by measure, we examined a variety of approaches to attribute the total value of the monetized NEIs among individual measures for use in cost-effectiveness (BCR) analysis. The number of measures that can contribute to LIMF NEIs is substantial and the causal pathways between the measures and impacts can be complex, making attribution of NEIs by measure for use in the PAs' BCR models challenging.

The 2016 Massachusetts study of LI Single-Family Health-and Safety-related NEIs[17] attributed the monetized NEI values to measures based on the contribution of each measure to total energy savings. For this study, we attempted to improve on this by developing an empirically grounded approach using regression analyses and composite NEI values.

There are two main categories of composite variables: (1) those created by averaging the values of several component variables and (2) those resulting from grouping component variables that can be meaningfully grouped. Weights can also be given to each component variable. The composite NEI variables created for these analyses are the latter type. We created composite variables in order to calculate the percent attribution of the total NEI value by measure. To produce a total composite NEI value, we weighted the composite variables for the attribution-by-measure approach by the monetized value of each NEI comprising it. (See Appendix A for detailed discussions of these calculations.)

In this approach, the dependent variable in the regression models is the change in composite NEI value and the independent variables are indicators for measures installed. Major measures included in the attribution analysis are air sealing, insulation, and heating systems.[18] Measures are represented as dummy variables so that the magnitudes of the beta coefficients can be consistently and directly interpreted as each measure's contribution to the NEI outcome. Since the avoided deaths component of Thermal Stress comprises a large part of the total NEI value, we used the composite NEI value for households where avoided deaths is included. (For more detail about avoided deaths, see Section 3.3.1.) We then took the difference in the pre- and post-composite NEI values and used it as the dependent variable. We also focused our analysis on measures most closely associated with reduction in Thermal Stress, as this NEI constituted the majority of the total NEI value. We ultimately selected a model that included air sealing, insulation, and heating system replacement or repair.

For regression estimates and calculations used to allocate the recommended NEI values to the relevant measures in the BCR models, see Section 2.4. For detailed regression analysis results see Section 2.3.2.

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[17] Three[3] and NMR. "Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts Study." Submitted to *Massachusetts Program Administrators and EEAC Consultants*, 2016. Massachusetts Special and Cross-Cutting Research Area. August 5, 2016 http://ma-eeac.org/wordpress/wp-content/uploads/Low-Income-Single-Family-Health-and-Safety-Related-NonEnergy-Impacts-Study.pdf.

[18] Even though indoor heat-related medical conditions are a current and growing concern, and cooling system improvements do reduce the at-times-fatal medical conditions, the Thermal Stress (Heat) analysis did not produce statistically defensible results. For this reason, we did not include the cooling systems measure in the attribution exercise.

Section 3 Results and Recommendations

This section presents the unadjusted results for all the NEIs subjected to difference in means tests, and the regression-adjusted results for the NEIs that showed statistically significant differences in means. Here, we describe in detail how we monetized the NEIs we are recommending the PAs adopt, and present the final monetized values for these NEIs. The detailed monetization methodology and estimated values for NEIs we are not recommending at this time can be found in Appendix A.2.

3.1 Unadjusted Estimates

To create the unadjusted estimates, we ran simple difference in means tests using either the CS or DID approach. For NEIs that we are recommending for adoption (other than Reduced Fire Risk), Table 9 presents the approach, unadjusted estimate of the change in rate of incidence, and level of statistical significance using a t-test for the NEIs this study recommends for adoption. Table 10 shows the change in rate of incidence for NEI indicators not recommended for adoption at this time.[19]

Appendix A.2.9 presents statistics for additional NEIs the team explored.

Table 9: Change in Incidence Rate – Approach, Deltas, and Statistical Significance for Recommended NEIs

NEI	Benefit Type	Selected Type of Analysis[1]	Difference in Means (Δ +/-)	p-value
Recommended NEIs				
Thermal Stress (Cold) – (mean # of doctor's office visits)[2]	HH & S	CS	-0.031	0.007**
Thermal Stress (Cold) – (mean # of emergency dept. visits)[3]	HH & S	CS	-0.016	0.024*
Arthritis Pain – (mean # of hospitalizations)[4]	HH & S	CS	-0.089	0.018*
Home Productivity – (mean # of "bad sleep" days)[5]	HH & S	CS	-0.980	0.059✧

[1] CS, using only Phase 1 data
[2] Data includes all persons in the home; n= 2008 (Tpre+C1); n= 879 (CwT).
[3] Data includes all persons in the home; n= 2008 (Tpre+C1); n= 879 (CwT).
[4] Data includes head of household only; n= 577 (Tpre+C1); n= 307 (CwT).
[5] Data includes head of household only; n= 963 (Tpre+C1); n= 468 (CwT).
✧ Difference is statistically significant at the p<0.1 level.
* Difference is statistically significant at the p<.05 level.
** Difference is statistically significant at the p<.01 level.

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[19] We calculated incidence rates using either Phase 1 data only (CS) or Phase 1 and Phase 2 data (DID). We then calculated an estimate of change (Δ +/-) using the difference in means from t-tests (either independent samples or paired samples t-tests).

Table 10: Change in Incidence Rate – Approach, Deltas, and Statistical Significance for NEIs NOT Recommended

NEI	Benefit Type	Selected Type of Analysis[1]	Difference in Means (Δ +/-)	p-value
NEIs Not Recommended for Adoption				
Missed Days of Work[2] (mean # of days)	HH & S	CS	-0.47	0.298
Food Spoilage[3] (mean # of times)[4]	HH	CS	-0.66	0.216
Thermal Stress (Cold)[5]	HH & S	CS		
Hospitalizations			-0.006	0.426
Thermal Stress (Heat)[5]	HH & S	CS		
Hospitalizations			-0.004	0.315
ED Visits			+0.006	0.320
Doctor's Office			-0.003	0.557
Asthma[6] (mean # of days)	HH & S	DID		
Hospitalizations			+0.16	0.172
ED Visits			+0.42	0.126
Urgent Care			+1.37	0.056✧

[1] CS using only Phase 1 data; DID using Phase 1 and Phase 2 data.
[2] Data includes head of household only; n= 219 (Tpre+C1); n= 84 (CwT).
[3] Data at household level; n= 37 (Tpre+C1); n= 173 (CwT).
[4] Based on the following NEI indicator: # of times had to throw food away due to spoilage in last 12 months.
[5] Data includes all persons in the home; n= 2008 (Tpre+C1); n= 879 (CwT).
[6] Data includes all persons in the home; n= (Tpre+C1); n= 879 (CwT).
✧ Difference is statistically significant at the p<0.1 level.

Table 11 presents statistically significant changes in rate of incidence from pre- to post-treatment of additional weatherization outcomes that help to substantiate three of the NEIs recommended for adoption: Thermal Stress (Cold), Arthritis, and Home Productivity. Post-weatherization, the Treatment group respondents report less frequent exposures to indoor drafts and unsafe temperatures, a decrease of 17% and 11%, respectively, at statistically significant levels. They also report statistically significant reductions in "hot or very hot" indoor temperatures (a decrease of 43%). Treatment group respondents' reports of "cold or very cold" indoor temperatures decreased, but by much less.

Statistically significant DID results provide further evidence that weatherization, not external factors, is the main driving force behind these outcomes; seven of the nine indicators presented in Table 11 had statistically significant DID results. The team found statistically significant reductions in the frequency of dust (-13%), outdoor noise (-12%) and sleep interference from it (-13%), and outdoor and indoor odors (-11% and -5%, respectively). Reductions in drafts, dust, noise, and odors indicate that the home is better sealed and insulated. See Appendix G for additional summary statistics related to dwelling quality and safety, general health, and household budget and affordability issues.

Table 11: Change in Incidence Rate and Statistical Significance of Supplemental Variables

NEI Indicators (not used for monetization)	Difference in Means (Δ +/-)					
Respondent Only	Treatment		Diff.	Control		DID
	T_Pre	T_Post		P1	P2	
Contributors to Reduced Thermal Stress and Arthritis[1]						
Home too drafty	34% (n=155)	17%	-17%***	17% (n=497)	9%	-8%
Unsafe or unhealthy indoor temperatures	40% (n=181)	29%	-11%**	20% (n=534)	13%	-4%
Hot or very hot indoor temps in the summer – past 12 mo	50% (n=185)	7%	-43%***	37% (n=536)	5%	-11%**
Cold or very cold indoor temps in the winter – past 12 mo	36% (n=183)	29%	-7%*	24% (n=532)	18%	-1%***
Contributors to Reduced Thermal Stress and to Increased Home Productivity (via sleep quality) [2]						
Home too dusty	42% (n=135)	26%	-16%***	28% (n=469)	25%	-13%**
Outdoor noise when windows are closed	31% (n=170)	20%	-11%**	21% (n=531)	22%	-12%**
Sleep interference from outdoor noise	28% (n=111)	16%	-12%*	12% (n=403)	14%	-13%*
Odors from outside	24% (n=134)	12%	-12%**	13% (n=408)	12%	-11%**
Odors from inside	38% (n=135)	31%	-8%	26% (n=412)	23%	-5%*

[1] These are indicators of improvements to indoor temperatures and comfort, both of which we would expect to contribute to reductions in thermal stress and in arthritis-related symptoms and medical visits.
[2] These are indicators of performance of insulation/air sealing that we would expect to contribute to reduced thermal stress and increased home productivity (via improved quality of sleep).
✧ Difference is statistically significant at the p<0.1 level.
* Difference is statistically significant at the p<.05 level.
** Difference is statistically significant at the p<.01 level.
*** Difference is statistically significant at the p<.001 level.

3.2 Regression-Adjusted Estimates

For the NEI indicators that showed statistically significant differences in means, we used regression analysis to test the statistical rigor of the indicator. The statistical significance of the regression-adjusted estimates helped determine which NEIs to recommend for adoption. As Section 2.2.3 notes, the regression analysis was meant to isolate the change in outcomes due to weatherization from outcomes due to regional, demographic, or other differences between the study groups.[20] The PA and EEAC Working Group agreed to use p-value <0.10 as an acceptable threshold of statistical significance for the regression-adjusted estimate for an NEI to be recommended for adoption. As Section 3.3.2 shows, the Thermal Stress NEI with Value of Statistical Life (VSL) included accounts for the bulk of the total NEI value. For this reason, the team ran individual regression models for the Thermal Stress NEI that isolated care settings. For both Thermal Stress (Cold) and Thermal Stress (Heat), the dependent variables were change in reported incidence of (1) doctor's office visits, (2) emergency department visits, and (3) hospitalizations. The detailed results of these models can be found in Appendix C.

The team developed ten models for three NEIs. The treatment effect from weatherization (the key coefficient in the regression model) estimated by four of the ten models was statistically significant for the following: doctor's office visits and emergency department visits due to Thermal Stress (Cold), hospitalizations due to Arthritis, and the number of bad days of sleep (associated with Home Productivity). The directionality of change (increase [+] or decrease [-]) for the treatment effect also indicated a decrease in medical encounters. The results give the team confidence in recommending the Thermal Stress (Cold), Arthritis, and Home Productivity NEIs for adoption.

Table 12 presents a summary of the ten models the evaluation team explored. Appendix C presents more detailed findings for each of the models.

[20] The team excluded asthma from the regression analysis because of the combination of the small sample size and the difference in asthma prevalence between the treatment and control group at baseline. The team did not expect the components of the unadjusted results for asthma to be statistically significant given the small sample that reported having asthma. Despite this, the DID estimate for one component of the three components of asthma – Urgent Care visits – was statistically significant and positive, suggesting that weatherization would lead to an increase in the incidence of asthma-related urgent care visits. It is important to note, however, that the proportion of the treatment group subsample with active asthma that reported having an asthma flare-up in the three months before the survey was lower than that of the control group (59% versus 78%, respectively). This suggests that a higher proportion of the control group had uncontrolled asthma at baseline. We would expect household members with uncontrolled asthma to be actively trying to control it, and thus more likely to seek care through doctor visits than urgent care. We suggest a future research study to explore whether this *negative* NEI outcome for the treatment group is founded.

Table 12: Summary of Regression Analysis Results

NEI	Dependent Variable (DV), Change in Incidence of Events	Key Independent Variable (IV)	β Coefficient	*p*-value
Arthritis	*Hospitalizations (mean)*	Weatherized (yes/no)	-0.074	0.094✧
Thermal Stress (Cold)	*Hospitalizations (mean)*	Weatherized (yes/no)	-0.010	0.262
Thermal Stress (Cold)	*ED visits (mean)*	Weatherized (yes/no)	-0.020	0.008**
Thermal Stress (Cold)	*Doctor's office visits (mean)*	Weatherized (yes/no)	-0.032	0.008**
Thermal Stress (Heat)	*Hospitalizations (mean)*	Weatherized (yes/no)	-0.002	0.542
Thermal Stress (Heat)	*ED visits (mean)*	Weatherized (yes/no)	+0.007	0.250
Thermal Stress (Heat)	*Doctor's office visits (mean)*	Weatherized (yes/no)	-0.003	0.250
Home Productivity	*# of bad days of rest/sleep*	Weatherized (yes/no)	-1.15	0.040*
Food Spoilage	*# of times thrown away food due to bad refrigerator*	Refrigerator installed (yes/no)	+0.055	0.522
Missed Days of Work	*# of days missed work due to illness/ injury (primary wage earner)*	Weatherized (yes/no)	+1.02	0.224

✧ Difference is statistically significant at the p<0.1 level.
* Difference is statistically significant at the p<.05 level.
** Difference is statistically significant at the p<.01 level.

3.3 Monetization of Recommended NEIs

Monetization entails 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 issues and household budgets as reported by residents on the resident survey. Below, we show how we monetized the avoided death benefit, which is fundamental to certain NEIs, and present the monetization inputs, algorithms, and estimated NEI values for the four NEIs we are recommending the PAs adopt.

3.3.1 Avoided Death Benefit

Two of the NEIs that we monetized – reduced Thermal Stress and Reduced Fire Risk – can be calculated either with or without the benefit of avoided deaths, also known as the VSL.[21] To monetize this benefit, we adopted the VSL value recommended by the U.S. Department of Transportation (DOT) ($9.6 million), which is similar to the VSL value used by the U.S. Environmental Protection Agency (EPA).[22,23,24]

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." [25]

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.[26] This is in accordance with Massachusetts guidelines for assessing the cost-effectiveness of the PAs' energy-efficiency programs, as the avoided death benefits assessed in this study are consistent with the allowable class of benefits that accrue to program participants.

We also explored the VSLs used by regulatory agencies in Massachusetts but did not find any in the published literature or through inquiries made to agency personnel. However, we did find a 2010 Massachusetts DOT publication that references the U.S. DOT's 2009 VSL to monetize the value of accidental traffic deaths that could be prevented through improvements to freight infrastructure and operations in the Commonwealth.[27]

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[21] 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

[22] 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).

[23] 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.

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

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

[26] With the exception of the VSL for firefighters.

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

3.3.2 Thermal Stress

We used responses to resident survey questions and inputs gleaned from secondary literature[28] to determine annual household and societal savings attributable to reduced medical treatment and avoided deaths due to exposure to extreme temperatures in the home.

For each healthcare setting (doctor's office, emergency department, and hospitalization), we calculated the change in number of visits reported to treat medical conditions associated with exposure to extreme indoor temperatures (Table 13). Due to the rarity of thermal stress events and the low sample size of the T_Post group, we used the cross-sectional, rather than DID, approach to calculate unadjusted change in incidence (ΔI). We used independent samples t-tests to establish the level of statistical significance.

Respondents were 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. Although there were fewer incidences of hospitalizations for heat-related stress post-weatherization, there was a slight *increase* in emergency department visits for heat, and the differences were not statistically significant.

We 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). None of the estimates of change for Thermal Stress (Heat) was statistically significant. Table 13 shows the side-by-side comparison of unadjusted and regression-adjusted estimates of change in incidence by care setting.

[28] 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.

Table 13: Comparison of Estimates of Change – Thermal Stress

Comparison of estimates of change (Δ)	Unadjusted Estimate of Δ		Regression-adjusted Estimate of Δ	
Parameter (n=2,887)	**Difference in Means[1]**	**p-value**	**β Coefficient**	**p-value**
Number of times stayed overnight in the HOSPITAL due to cold	-0.006	0.426	-0.010	0.262
Number of times went to EMERGENCY ROOM due to cold	-0.016	0.024*	-0.020	0.008**
Number of times went to DOCTOR'S OFFICE due to cold	-0.031	0.007**	-0.032	0.008**
Number of times stayed overnight in the HOSPITAL due to heat	-0.004	0.315	-0.002	0.542
Number of times went to EMERGENCY ROOM due to heat	+0.006	0.320	+0.007	0.250
Number of times went to DOCTOR'S OFFICE due to heat	-0.003	0.557	-0.003	0.250

[1] $[(\Delta I) = I_{CwT} - (I_{Tpre+C1})]$
* Difference is statistically significant at the p<.05 level.
** Difference is statistically significant at the p<.01 level.

Since the estimate of change for heat stress encounters did not meet the threshold of p<.10 for statistical rigor, we are not recommending the Thermal Stress (Heat) NEI, although we believe the benefits are substantial and important.

For comparison purposes, we monetized the NEI for reduced medical encounters using both the unadjusted and the regression-adjusted estimates of change. We recommend that the PAs adopt the monetized NEI value based on the regression-adjusted estimate because the regression adjustment better isolates the impact of weatherization from other confounding factors. 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. (See Appendix D for a detailed discussion of thermal stress-related fatalities.) We calculated the value of avoided deaths from reductions in thermal stress using the estimate of change of emergency department visits. Table 14 presents the monetization approach and inputs. To simplify the table, we used cost multipliers to capture costs by payer, percent of out-of-pocket (OOP) costs based on type on insurance, and percent of annual treatment costs by payer and by care setting type.

Table 15 presents cost multiplier calculations.

Table 14: Monetization Approach and Inputs – Thermal Stress

	Metric / Measure	NEI: Cold Stress Emergency Dept. (ED) Visits	NEI: Cold Stress Doctor Visits	NEI: Cold Stress Avoided Deaths	Total NEI Value
Estimate of Δ					
[A]	Regression model coefficient	-0.020	-0.032	Uses ED visits (-0.020)	NA
[B]	Other Δ estimate (difference in means)	-0.016	-0.031	Uses ED visits (-0.016)	NA
Monetization Parameters					
[C]	Cost multiplier (per person)	$210	$29	$46,648	NA
[D] = [C] * 1.52	Cost multiplier (per household)	$320	$44	$70,905	NA
Monetized NEI					
[E] = [A] * [D]	**Monetized estimate, per household, using [A]**	**$6**	**$1**	**$1,418**	**$1,426**
[F] = [B] * [D]	Monetized estimate, per household, using [B]	$5	$1	$1,134	$1,141

Notes/sources:

- [A] = See Appendix C for regression model specifications yielding the coefficients in this table.
- [B] = Calculated **change in incidence (Δ) by using the difference in means = [(ΔI) = I_{CWT} – ($I_{Tpre+C1}$)]. Used independent samples t-test for testing statistical significance (doctor's office, p=.007; emergency department visits, p=.024).**
- [C], [D] = Cost multipliers are presented here to simplify the table. Cost multipliers capture costs by payer, percent of OOP costs based on type on insurance, and percent of annual treatment costs by payer and by care setting type. Calculations for cost multipliers are provided in
- Table 15.
- [E], [F} = Due to rounding, calculations might not provide exact values. The team reports up to three decimal points, but the calculations used to derive the incidence rates use unrounded values.

Table 15: Calculations for Cost Multipliers (Household Benefit Only) – Thermal Stress (Cold)

Calculations for Cost Multipliers - Monetization of Thermal Stress (Cold) NEI		
Multipliers for each care setting = (% of costs paid by p_2 * C$ paid by p_2 * % of OOP costs from p_2) + (% of costs paid by p_3 * C$ paid by p_3 * % of OOP costs from p_2)		
	a. Doctor Office Visits	**b. Emergency Dept. Visits**
% of costs by payer[1]		
p_1 = Public	32%	42%
p_2 = Private/Other	56%	22%
p_3 = Uninsured	11%	37%
OOPs[2, 3]		
Percent OOPs – publicly insured	5%	5%
Percent OOPs – private/other insured	10%	10%
Percent OOPs – uninsured	44%	44%
Cost (C$) by Payer [4]		
p_1 = Average Public Insurance	$175.28	$820.95
p_2 = Average Private/Other	$354.71	$1,739.12
p_3 = Average Uninsured	$126.48	$959.35
Per person cost multiplier, per year	$28.93	$210.22
Mean household size (=1.52 persons)		
Household NEI cost multiplier for Thermal Stress (Cold)	**$43.97**	**$319.53**

[1] Medical Expenditure Panel Survey (MEPS) – 2015.
[2] Center for Financing, Access and Cost Trends, AHRQ, MEPS, 2017.
[3] Reference Table: Median expenditures per person with expense by source of payment and insurance coverage, United States, 2017. https://meps.ahrq.gov/mepstrends/hc_use/
[4] Bureau of Labor Statistics. Consumer Price Index to price-adjust medical costs for MA, 2020. https://data.bls.gov/timeseries/CUURS11ASAM?amp%253bdata_tool=Xgtable&output_view=data&include_graphs=true

The team calculated the value of avoided deaths by multiplying the change in incidence rate Δ by the rate of emergency department visits (due to cold-related thermal stress) that result in death, multiplied by the VSL. Our analysis determined that 14.8 deaths caused by cold stress were prevented annually in Massachusetts per 100,000 units weatherized in the state. Table 16 shows these values and provides the inputs used to calculate them and the total value of the avoided death benefit for cold stress.

Table 16: Estimating Avoided Deaths from Extreme Cold Stress

	Inputs	Cold-Stress
[A]	Regression-adjusted estimate of change – # of emergency dept. visits for cold stress, *per person*	-0.020
[B]	% of deaths caused by exposure to extreme cold temperatures following emergency dept. visits (national rate) [29]	0.486%
[C] = [A] * [B]	Rate of reduction in deaths caused by cold stress	0.010%
[D]= [C] * 1.52	Rate of reduction in deaths caused by cold stress, per household	0.019%
*[E] = [D] * 100,000*	*Number of avoided deaths post-weatherization, per 100,000 weatherized units*	*14.8 deaths*
NEI = [E] * $9.6M	**Avoided death benefit, per weatherized unit, per year**	**$1,418**

We are recommending a thermal stress-related NEI value (Thermal Stress [Cold]) of **$1,426** from reduced doctor's office and emergency department visits and from avoided deaths due to reductions in unsafe cold temperatures (Table 17). This recommendation only includes the household benefit. Table 17 also presents the estimated societal benefit of the Thermal Stress (Cold) NEI.

Table 17: Estimated Annual Impact of Reduced Thermal Stress (Cold)

Thermal Stress (Cold) NEI	Annual Per Unit Benefit	Annual Per Unit Benefit W/O Avoided Death Benefit
Household	**$1,426***	$8
Society	$38	$38
Total	**$1,464**	**$46**

[29] HCUP parameters are as follows:

- Weighted national estimates from HCUP National (Nationwide) Emergency Department Sample (NEDS), [2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014], AHRQ, based on data collected by individual States and provided to AHRQ by the States.
- Total number of weighted visits in the U.S. based on HCUP NEDS = 120,033,750 (2006); 122,331,739 (2007); 124,945,264 (2008); 128,885,040 (2009); 128,970,364 (2010); 131,048,605 (2011); 134,399,179 (2012); 134,869,015 (2013); 137,807,901 (2014). We used an average of the most recent two years: 2013, 2014.
- Statistics based on estimates with a relative standard error (standard error / weighted estimate) greater than 0.30 or with standard error = 0 in the nationwide statistics (NIS, NEDS, and KID) are not reliable. These statistics are suppressed and are designated with an asterisk (*).

Source: HCUPnet, Healthcare Cost and Utilization Project. AHRQ, Rockville, MD. https://hcupnet.ahrq.gov/. For more information about HCUP data, see http://www.hcup-us.ahrq.gov/

3.3.3 Arthritis

Arthritis prevalence (i.e., respondents self-reporting current arthritis) for the weatherized group for all regions combined was 49%. We calculated the Arthritis NEI using responses to arthritis-related hospitalization questions asked of the head-of-household in the resident survey. We 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 (Table 18). We 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). We gathered medical expenditure data for urgent care from the MEPS for arthritis-related outpatient care and emergency department costs.[30] We inflated medical costs data for all treatment types to 2020 costs and adjusted them to reflect costs in Massachusetts. We calculated household and societal costs for the Arthritis NEI using data from the MEPS and the Kaiser Family Foundation's (KFF) State Health Facts.[31,32]

Arthritis has the potential to be a particularly important NEI for the PAs. The varying forms of arthritis are known to limit mobility, daily activities, ability to work, and quality of sleep. They are also known to influence pain medication. All of these can contribute to overall quality of life.[33]

Patients with osteoarthritis are sensitive to cold temperatures.[34] In a related literature review, the authors state that both temperature and humidity appear to worsen symptoms of rheumatoid arthritis. In a 2015 examination of the influence of weather on elderly osteoarthritis sufferers, conditions that were significantly associated with pain were daily average humidity, three-day average humidity, and the interaction between daily average humidity and temperature. In a 2012 study, the authors investigated potential weather factors influencing rheumatoid arthritis emergency department visits and determined statistical significance for daily mean temperature and emergency department visits for respondents in the 50-65 age range.[35] Studies surveying patients with any type of arthritis report that shifts in atmospheric pressure, humidity, temperature, or some combination of all three factors heighten their pain.[36]

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[30] The team 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.

[31] Reference Table: Median expenditures per person with expense, by source of payment and insurance coverage, United States, 2017. https://meps.ahrq.gov/mepstrends/hc_use/

[32] KFF. Health Insurance Coverage of the Total Population. Retrieved from: https://www.kff.org/state-category/health-coverage-uninsured/

[33] Informed Health. Everyday Life with Rheumatoid Arthritis (NCBI, 2013), accessed March 21, 2019, https://www.ncbi.nlm.nih.gov/books/NBK384458/

[34] Penny Moss, Emma Knight, and Anthony Wright. "Subjects with Knee Osteoarthritis Exhibit Widespread Hyperalgesia to Pressure and Cold," PLoS One 11, no. 1 (2016), accessed March 21, 2019, https://doi.org/10.1371/journal.pone.0147526

[35] Lydia Abasolo, Aurelio Tobías, Leticia Leon, Loreto Carmona, Jose Luis Fernandez-Rueda, Ana Belen Rodriguez, Benjamin Fernandex-Gutierrez, and Juan Angel Jover. "Weather Conditions May Worsen Symptoms in Rheumatoid Arthritis Patients: The Possible Effect of Temperature," Reumatología Clínica 9 no. 4, (2012), accessed March 21, 2019. https://doi.org/10.1016/j.reuma.2012.09.006

[36] Josep Vergés, Eulàlia Montell, Elena Tomàs, Gemma Cumelles, Guido Castañeda, Núria Martí, and I. Moller. "Weather Conditions can influence rheumatic diseases." Proceedings of the Western Pharmacology Society 47 (2004): 134-6, accessed March 21, 2019, https://doi.org/10.1016/j.reuma.2012.09.006

It seems reasonable to hypothesize that stabilizing indoor conditions could reduce weather-related arthritis flare-ups and chronic pains.[37] Evidence in literature suggests that fewer fluctuations in temperatures and more comfortable temperature settings and relative humidity levels reduce the severity of pain experienced by at least some percentage of arthritis sufferers and potentially improve overall quality of life.[38,39,40,41,42,43]

Table 18 shows that of those that reported having been diagnosed with arthritis, the number of hospitalizations for worsening pain decreased at statistically significant levels for both the unadjusted and regression-adjusted estimates of change. The data show a decrease in the number of medical encounters at the other care settings (ED and urgent care clinic). The unadjusted estimates were statistically significant using the difference in means test but the regression-adjusted estimates were not. Thus, the emergency department and urgent care settings were not included in the monetization equation.

Table 18: Comparison of Estimates of Change − Arthritis

Comparison of estimates of Change (Δ)	Unadjusted Estimate of Δ		Adjusted Estimate of Δ	
Parameter (n=877)	Mean Difference[1]	p-value	β Coefficient	p-value
Number of hospitalizations for worsening arthritis	-0.089	0.018	-0.074	0.094✧
Number of emergency dept. visits for worsening arthritis	-0.076	0.096	-0.063	0.251
Number of visits to urgent care clinic for worsening arthritis	-0.156	0.009	-0.044	0.568

[1] $[(\Delta I) = I_{CwT} - (I_{Tpre+C1})]$

✧ Difference is statistically significant at the p<0.1 level.

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[37] Erik J. Timmermans, Suzan Van Der Pas, Laura A. Schaap, Mercedes Sánchez-Martínez, Sabina Zambon, Richard Peter, Nancy L. Pedersen et al. "Self-perceived weather sensitivity and joint pain in older people with osteoarthritis in six European countries: results from the European Project on OsteoArthritis (EPOSA)." BMC Musculoskeletal Disorders 15, no. 1 (2014): 66.

[38] Scott Pigg, Dan Cautley, Paul Francisco, Beth A. Hawkins, and Terry M. Brennan. Weatherization and Indoor Air Quality: Measured Impacts in Single Family Homes Under the Weatherization Assistance Program. No. ORNL/TM-2014/170. Oak Ridge National Lab. (ORNL), Oak Ridge, TN (United States), 2014.

[39] Bruce E. Tonn, B., Beth Hawkins, B., Erin Rose, E., and Michaela Marincic, M. “Energy and Non-Energy Impacts of Weatherizing Low-Income Multifamily Buildings: Summary of Results from the Evaluations of the U.S. Department of Energy’s Weatherization Assistance Program”. Three[3], Inc., Knoxville, TN, September., 2017.

[40] Larson, A. A., Pardo, J. V., & Pasley, J. D. (2014). Review of overlap between thermoregulation and pain modulation in fibromyalgia. The Clinical journal of pain, 30(6), 544–555. https://doi.org/10.1097/AJP.0b013e3182a0e383

[41] Farbu EH, Skandfer M, Nielsen C, et al. Working in a cold environment, feeling cold at work and chronic pain: a cross-sectional analysis of the Tromsø Study. BMJ Open 2019;9:e031248. doi: 10.1136/bmjopen-2019-031248

[42] Abasolo L, Tobias A, Leon L, Carmona L, Fernandez-Rueda JL, Rodriguez AB, et al. Weather conditions may worsen symptoms in rheumatoid arthritis patients: the possible effect of temperature. Reumatol Clin. 2013;9:226–8.

[43] Feldthusen C, Grimby-Elkman A, Forsblad-d’Elia H, Jacobsson L, Mannerkorpi K. Seasonal variations in fatigue in persons with rheumatoid arthritis: a longitudinal study. BMC Musculoskelet Disord. 2016;17:59.

We monetized the NEI for reduced hospitalizations due to worsening arthritis symptoms using the monetization approach and inputs presented in Table 19 and inputs presented in Table 20.

Table 19: Monetization Approach and Inputs − Arthritis

	Metric / Measure	NEI: Arthritis Hospitalizations
[A]	Regression model coefficient	-0.074
[B]	Other Δ estimate (difference in means)	-0.089
[C]	Cost multiplier, per household	$1,346
[D]	Arthritis prevalence among program homes	49.4%
[E] = [A] * [C] * [D]	**Monetized estimate, per household, using [A]**	**$49**
[F] = [B] * [C] * [D]	Monetized estimate, per household, using [B]	$59

Notes/sources:

- [A] = See Figure 3 in Appendix C for regression model specifications yielding the coefficients in this table for the Arthritis NEI. **The recommended NEI value for arthritis is based on the regression-adjusted estimate for change in (mean) number of arthritis-related hospitalizations.**
- [B] = **For the Arthritis NEI, calculate change in incidence (ΔI) using the difference in means = [(ΔI) = I_{CwT} – ($I_{Tpre+C1}$)]. Used independent samples t-test to test for statistical significance (p=.018)**. See Section 2.3.1 for details on calculating incidence rates. Table 9 presents changes in incidence rates for the Arthritis indicators.
- [C] = Cost multipliers are presented here to simplify table. Cost multipliers capture costs by payer, percent of OOP costs based on type on insurance, and percent of annual treatment costs by payer and by care setting type.
- [D] = The percent of CwT and T (i.e., program) homes that reported having arthritis.
- [E] = Unlike thermal stress-related questions, questions related to arthritis indicators were asked only of the main respondent. Thus, it is not prudent to apply the 1.52 multiplier (mean number of persons per household). We present monetized values for arthritis at the household-level only.

Table 20: Calculations for Cost Multipliers (Household Benefit Only) - Arthritis

Calculations for Cost Multipliers - Monetization of Arthritis NEI	
Multipliers for each care setting = C$* (% of costs paid by p_2 * % of OOP costs from p_2) + (% of costs paid by p_3 * % of OOP costs from p_2)	
	a. Hospitalizations
% of Costs by Payer [1]	
p_1 = Public	58%
p_2 = Private/Other	40%
p_3 = Uninsured	<1%
OOPs[2, 3]	
p_1 = Public	8%
p_2 = Private/Other	13%
p_3 = Uninsured	100%
Average Cost (C$) [4]	
Average Cost for Hospitalizations	$13,680
Household NEI Cost Multiplier - Arthritis	**$1,346**

[1] MEPS – 2015.
[2] Center for Financing, Access and Cost Trends, AHRQ, MEPS, 2017.
[3] KFF – State Health Facts. Retrieved from: https://www.kff.org/state-category/health-coverage-uninsured/
[4] Bureau of Labor Statistics. Consumer Price Index to price-adjust medical costs for MA, 2020. https://data.bls.gov/timeseries/CUURS11ASAM?amp%253bdata_tool=Xgtable&output_view=data&include_graphs=true

We are recommending an Arthritis NEI value of **$49** attributable to reductions in hospitalizations due to worsening arthritis symptoms. This recommendation only includes the household benefit. Table 21 also presents the estimated societal benefit.

Table 21: Estimated Impact of Reduced Arthritis

Arthritis NEI	Annual Per Unit Benefit
Households	**$49**
Society	$892
Total	**$941**

3.3.4 Home Productivity

For the Home Productivity NEI, we relied on responses to the resident survey question related to number of days of poor sleep and inputs identified in the secondary literature 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 team's research findings indicate that there are reductions in reports of *poor* sleep from respondents that are weatherization recipients. We found that levels of outdoor noise and disturbance from outdoor noise, which can contribute to poor sleep and negative health outcomes, were lower for the Comparison-with-Treatment group. For example, the percentages of the Comparison-with-Treatment group that reported hearing a great deal of outdoor noise and having sleep interfered with by outdoor noise either "extremely" or "very much" were lower by 12% and 13%, respectively.

Table 22 shows that the estimate of change for the Home Productivity indicator (# of poor sleep days in the past 30 days) has a negative value. Both unadjusted and regression-adjusted estimates are statistically significant.

The monetization of the Home Productivity NEI is based on a change in number of poor sleep days (in the past 30 days) using the monetization approach and inputs presented in Table 22 and Table 23.

Table 22: Monetization Approach and Inputs – Home Productivity

	Metric / Measure	NEI: Home Productivity
Estimate of Δ		
[A]	Regression model coefficient	-1.151
[B]	Other Δ estimate (difference in means)	-0.98
Monetization Parameters		
[C] = [A] / 30 days	% change over last 30 days	-3.837%
[D] = [B] / 30 days	% change over last 30 days	-3.267%
[E]	Cost multiplier, per household	$1,275
Monetized NEI		
[F] = [C] * [E]	**Monetized estimate, per household, using [A]**	**$49**
[G] = [D] * [E]	Monetized estimate, per household, using [B]	$42

Notes/sources:

- [A] = See Figure 7: in Appendix C for regression model specifications yielding the coefficients in this table. **The recommended NEI value for Home Productivity is based on the regression-adjusted estimate for change in (mean) number of days (over last 30 days) of poor rest or sleep.**
- [B] = **Calculated change in incidence (ΔI) using the difference in means = [(ΔI) = I_{CwT} – ($I_{Tpre+C1}$)]. Used independent samples t-test to test for statistical significance (p=.059)**. See Section 2.3.1 for details on calculating estimates of change.
- [E] = Cost multipliers are presented here to simplify the table. Cost multipliers capture annual productivity increases attributable to better sleep and rest ($), average annual salary for a U.S. worker, the value of an hour of housework, and % of main respondents employed.

Table 23: Monetization Approach – Home Productivity

Calculations for Cost Multipliers - Monetization of Home Productivity NEI	
Multiplier = (I*W*H*52)	
P = Annual productivity increases attributable to better sleep and rest[1]	$2,500
S = Average annual salary of a U.S. worker ($)[2]	$50,054
I = Productivity increase in housework (=P/S)	5%
W = Value of an hour of housework[3]	$22.80
H = Hours per week spent on housework[4]	21.5 hours/week
Number of weeks/year	52 weeks
Household NEI Cost Multiplier – Home Productivity	$1,275

[1] https://www.rand.org/pubs/research_reports/RR1791.html
[2] https://www.census.gov/newsroom/releases/archives/income_wealth/cb12-172.html
[3]https://www.forbes.com/sites/jennagoudreau/2011/05/02/why-stay-at-home-moms-should-earn-a-115000-salary/#5bb109f275f4
https://www.bea.gov/household-production/
[4] http://www.bls.gov/opub/mlr/2009/07/art3full.pdf

We recommend an annual NEI value of **$49** for increased Home Productivity (Table 24). This recommendation only includes the household benefit. Table 24 also presents the estimated societal benefit of increased home productivity due to improved sleep.

Table 24: Estimated Impact of Increased Home Productivity Due to Improved Sleep

	Annual Per Unit Benefit
Households	**$49**
Society	$0
Total	**$49**

3.3.5 Reduced Fire Risk

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. There were no statistically significant changes in the frequency of building or unit fires from Phase 1 to Phase 2, which was to be expected given the sample sizes and the rarity of home fires.

We used inputs mined from secondary literature to estimate annual household and societal savings attributable to reduced medical treatment and avoided deaths from reduced occurrences of home fires. For the Reduced Fire Risk NEI, the team derived the reduced probability of fire (-0.0003) in a MF unit from the reduced probability of fire in a LISF home.[44] (The findings from the resident survey, presented in Table 87 in Appendix G.1, are only meant to substantiate the secondary data, not to be incorporated into the monetization algorithm.)

[44] Hawkins et al. 2016

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. Based on the limited data provided by participating agencies, it appears that no smoke detectors were installed as part of MF weatherization (see Appendix F).

We monetized the NEI for reduced home fire occurrences using the monetization approach and inputs presented in Table 25 and Table 26, respectively.

Table 25: Monetization Approach – Reduced Fire Risk

Monetization Approach
Key Variables
• A_1 = probability of fire in MF apartment • B_1 = reduced probability of fire in MF apartment, attributable to weatherization • A_2 = probability of fire in SF home • B_2 = reduced probability of SF fire, attributable to weatherization • C = estimated occupant deaths from an apartment fire • D = estimated occupant injuries from an apartment fire • E = estimated cost of occupant injuries per apartment fire (HH) • F = estimated cost of occupant injuries per apartment fire (S) • G = estimated firefighter deaths per apartment fire • H = estimated firefighter injuries per apartment fire • I = estimated cost of firefighter injuries (HH) • J = estimated cost of firefighter injuries (S) • K = estimated property loss per apartment fire • L = estimated property loss (HH) • M = estimated property loss per apartment fire (S) • N = value of avoided death
Equation 1. *Reduced probability of MF unit fire, attributable to weatherization*
• $B_1 = A_1*(B_2 / A_2)$ • $B_1 = 0.0011*(0.000585/0.0021)$
Equation 2. *Annual Societal Benefit (per weatherized unit)*
• $= B_1*(G*N) + (H*(F+J) +M))$ • *Societal NEI = 0.00030643*((0.00005*$9.6M) + (0.1*($7,237+$8,614)) + $11,968))*
Equation 3. *Annual Household Benefit (per weatherized unit)*
• $= B_1*((C*N) + (D*(E+I)) + L)$ • *Household NEI = 0.00030643*((0.0037*$9.6M) + (0.0183*($1,391+$0) + $6,732))*

Table 26: Sources/Inputs – Reduced Fire Risk

Inputs/Sources	
Literature: Peer Reviewed and Other	• Estimated S benefits per weatherized SF unit: Hawkins et al. 2016 • Estimated HH benefits per weatherized SF unit: Hawkins et al. 2016 • Adjusted SF fire reduction rates from Hawkins et al. 2016 to MF sector: • https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics/Occupancies/osHomes.pdf • https://www.verisk.com/blog/fire-trends-multifamily-housing/ • https://www.usfa.fema.gov/downloads/pdf/statistics/v18i3.pdf
Open-Source Databases	• Bureau of Economic Analysis: Regional Price Parity to adjust national cost estimates to MA price levels[1] • Bureau of Labor Statistics: Consumer Price Index to price-adjust medical costs from 2008 to 2020[2]

[1] https://apps.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=8#reqid=70&step=1&isuri=1
[2] https://data.bls.gov/timeseries/CUURS11ASAM?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

We recommend a Reduced Fire Risk NEI value of **$13**. This recommendation only includes the household benefit. Table 27 also presents the estimated societal benefit and the annual impact of reduced occurrences of home fires.

Table 27: Estimated Impact of Reduced Home Fire Occurrences

Reduced Fire Risk NEI	Annual Per Unit Benefit	Annual Per Unit Benefit W/O Avoided Death Benefit
Households	**$13**	$2
Society[1]	$4	$4
Total	**$17**	**$6**

[1] Avoided injuries and deaths to firefighters are categorized as a societal benefit.

3.4 Recommended NEIs

The PA and EEAC Working Group agreed that only those NEIs that met the following three criteria, if applicable, would be recommended for adoption:

1. The impacts are at the household, not societal, level. This is because the PAs cannot currently claim NEIs at the societal level. For this reason, we excluded for consideration Work Productivity, Prescription Adherence, and Food Assistance, and did not address these in the regression analysis above.
2. The impacts are not derived from energy bill savings, as agreed-upon with the PA Working Group.[45] This is because of the potential for double-counting the benefits. For this reason, we excluded from regression analysis Short-term loans, Low-Birth-Weight Infants, Prescription Adherence, and Food Assistance.
3. For NEIs that rely on primary data, both the results of the difference in means analysis (unadjusted estimate) and the coefficient of the weatherization variable in the regression model (regression-adjusted estimate) are statistically significant, at p-value <.10 for the outcome of interest. For the one NEI that relies on secondary data only (Reduced Fire Risk), there is sufficient incidence rate and risk factor data from secondary sources to monetize the NEI from these sources.

The **Arthritis**, **Thermal Stress (Cold), Home Productivity, and Reduced Fire Risk NEIs** meet all the criteria, and thus we recommend that the PAs adopt their monetized values.

3.4.1 Recommended NEI Values

Table 28 summarizes the individual monetized values for the four recommended NEIs presented above – broken out into both household and societal benefits.

Although the mathematical monetization algorithms used precise values for inputs, here, we present NEI values rounded to the nearest dollar to avoid conveying a false sense of the precision of these values. For the unrounded NEI values, see Appendix I.

We recommend the PAs adopt the monetary valuations for the four LIMF health-and-safety-related NEIs presented below. The valuations should include VSL, as applicable, and be applied per housing unit per year, assuming one household per weatherized housing unit. The values for each NEI are Arthritis, $49; Thermal Stress (Cold), $1,426; Reduced Fire Risk, $13; and Home Productivity, $49. The sum total value of the recommended household (HH) NEI values per unit, excluding societal benefits, is $1,537 (as presented in the "Per HH w/ VSL" column, highlighted in green).

Although the PAs are only able to claim household benefits at this time, we also present the societal benefits. The sum total of the household and societal NEI values including VSL is $2,471.

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[45] A key consideration when quantifying NEIs is to ensure that the impacts do not overlap with other benefits that have already been accounted for elsewhere, such as energy savings. This avoids double-counting. The Working Group identified NEIs with the potential for double-counting prior to the completion of Phase 2 data collection. These NEIs are documented in the August 22, 2019 memo entitled "TXC50 Methodological Challenges and NEI Study Group Discussions."

Table 28: Estimated Annual Values of Recommended NEIs Per Weatherized Housing Unit
(With and Without VSL)

NEI Values	Per HH[1] w/ VSL	Per HH w/o VSL	Societal	Total	Total w/o VSL
Arthritis	$49	$49	$892	$941	$941
Thermal Stress (Cold)	$1,426†	$8	$38	$1,464	$46
Home Productivity	$49	$49	$0	$49	$49
Reduced Fire Risk	$13	$2	$4	$17	$6
Annual Total of Recommended NEIs per Weatherized Housing Unit	**$1,537**	**$108**	**$934**	**$2,471**	**$1,042**

[1] HH = household (assuming one household per housing unit).
† The total Thermal Stress (cold) NEI of $1,426 includes doctor's office visits ($1.41) + emergency dept. visits that do not result in deaths ($6.39) + the value of avoided death ($1,418).

3.5 Attribution by Measure

We ran another series of regression models as a simple, defensible way to determine how to allocate the recommended NEI values to the relevant measures in the BCR models. This analysis used the difference of the pre- and post-household composite NEI values as the dependent variable and the indicators for installed measures as the independent variables (see Appendix H for more details).

One of the first models we examined included three independent dummy variables: heating system upgrades (repair/replacement), air sealing, and insulation. We found high collinearity between air sealing and insulation: 87% of units that received insulation also received air sealing, while 78% of units that received air sealing also received insulation. This greatly reduced the impact of the insulation dummy variable. We created a dummy composite variable that combined air sealing and insulation (Air Sealing+Insulation) into one independent variable. Ultimately, our final recommended model produced statistically significant p-values with consistent directionality of the beta coefficients. The two independent variables in the recommended model were (1) Air Sealing+Insulation composite and (2) heating system upgrades. In this model, the magnitude of the normalized beta coefficients also aligned with expectations. Table 29 shows a summary of the results using the total NEI value composite variable (the difference between Phase 1 and Phase 2 total household NEI value including VSL) as the dependent variable (discussed in Section 2.4). For more detailed regression analysis results, see Appendix C.

Table 29: Regression Analysis Results – Attribution by Measure

NEI Values	Independent Variables	β Coefficient	p-value
Dependent Variable: *(Difference between Phase 1 and Phase2 VSL Composite NEI Value)*	Air Sealing+Insulation (X)	-288.960	0.056✧
	Heating System Upgrades (Y)	-312.367	0.029*

✧ Difference is statistically significant at the p<0.1 level.
* Difference is statistically significant at the p<.05 level.

The team used Equations 1 and 2 below to normalize the impacts of the beta coefficients.

- Air sealing + insulation (X)
- Heating system upgrades (Y)

Equation 1: *% attribution for(X) = % of measure combination X / (sum of % of measure combination X + Y)*

-288.96 / (-288.96 + -312.367) = 48**% attribution for** X

Because of the frequency with which air sealing and insulation are installed together, and the similarity in their installation rates (55% for air sealing and 50% for insulation), we recommend evenly splitting attribution for these measures, as follows:

- 48% attribution for X = **24**% for air sealing and **24**% for insulation

Equation 2: *% attribution for Heating System Upgrades (Y) = % of measure Y / (sum of % of measure combination X + Y)*

- -312.367/(-288.96 + -312.367) = **52% attribution for heating system upgrades**

3.5.1 Recommended NEI Allocation by Measure

In summary, the analysis above attributes the recommended NEIs to air sealing, insulation, and heating system upgrades. The value of each recommended NEI should be allocated across these measures as follows:

- **Air sealing: 24%**
- **Insulation: 24%**
- **Heating system upgrades: 52%**

For example, the annual total value of recommended NEIs per weatherized housing unit, $1,537, should be allocated across these measures, as follows:

- **Air sealing: $369**
- **Insulation: $369**
- **Heating system upgrades: $799**

3.6 LIMF VERSUS LISF

From a building science perspective, a LIMF building behaves differently from a LISF home. LIMF and LISF weatherization measures differ as well. The evidence presented here suggests that both LIMF NEIs and their values differ from those of LISF, and thus LISF NEIs should not be applied to LIMF.

Here, we focus on the LIMF Thermal Stress (Cold) NEI value. (The team did not consider Arthritis for the LISF study). The Thermal Stress (Cold) NEI value for LIMF is 32% higher than the same NEI for LISF (a $963 difference). We believe that the LISF NEI value may be undervalued due to the greater rigor of the resident survey questions for LIMF than for LISF.

Specifically, the LIMF survey asked about all persons in the home, asked questions to identify the care setting, and asked the number of times medical attention was sought per care setting per person. The LISF survey only asked about the head of household, did not identify the type of care setting, and did not ask the number of times medical attention was sought.

Had the LISF study asked about all persons in the home, the values for the Thermal Stress (Cold) NEI from that study would likely have doubled, making the LISF and LIMF NEI values comparable. Had the LISF study also asked questions to identify the care setting and the number of times medical attention was sought per care setting per person, the LISF values for Thermal Stress (Cold) might have been even greater than the LIMF values.

In addition, there were differences between the LIMF and LISF samples that would lead us to expect a difference in Thermal Stress (Cold) NEI values between the participants living in LIMF and LISF homes. Overall, the LIMF study groups were older than those in the LISF. The Massachusetts LIMF sample had more public housing than the LISF sample, and more of this housing may have been senior-focused. This could explain why Thermal Stress (Cold) and Arthritis are among the recommended LIMF NEIs, but not NEIs that would likely be more prevalent among a younger population, such as Missed Days of Work or Asthma. (Age was statistically significant in the regression model for doctor's office visits due to cold thermal stress and hospitalizations for arthritis.) Table 30 compares the Thermal Stress (Cold) NEI values for LISF versus LIMF both with and without the avoided death benefit.

Table 30: Comparison of LIMF and LISF Thermal Stress (Cold) Values

	With Avoided Death Benefit	W/O Avoided Death Benefit (out of-pocket expenses only)
LISF (Cold Stress Only)*	$463	$5
LIMF (Cold Stress Only)	**$1,426**	$8

* The LISF study estimated heat stress separately from cold stress, and recommended an NEI for Thermal Stress (Heat). The value of LISF NEI for Thermal Stress (Heat) alone is $146.

3.7 CONSIDERATIONS

3.7.1 Lessons Learned for Future NEI Studies

The team identified lessons from this study that could improve the PAs' future NEI research. Several of these lessons would need to be implemented well before a new NEI study begins in order to be effective, or could be implemented with the next NEI study of any type. The lessons that are in italics are ones that could be implemented immediately.

1. **When planning future studies of this type, PAs and their evaluators should focus on a narrower range of NEIs.** This study provided evidence suggesting that certain NEIs are worth examining further. In particular, the food spoilage and heat stress NEIs were close to, but did not meet, the threshold for statistical rigor. The fact that the Control group reported better asthma-related healthcare outcomes than the Treatment group suggests that it may be worthwhile to investigate asthma NEIs further. Should the PAs choose to study asthma further, it should be with a larger Treatment group that has a higher baseline rate of uncontrolled asthma, more similar to that of the Control group.

   Examining a narrower range of NEIs such as these would mean a shorter survey, and the lower response burden would likely result in higher response rates and larger groups. Another way to boost group sizes is to supplement the current dataset with new data on a narrower range of NEIs, and reanalyze it to yield more definitive results for the selected NEIs. If the new federal administration passes a recovery or infrastructure act that includes substantial funding for WAP, it could present a prime opportunity to scrutinize these NEIs as well as ones that met this study's statistical rigor threshold.

2. **When planning future studies of thermal stress-related NEIs, evaluators should consider using changes in hospitalizations, as well as emergency department visits, to establish the avoided death benefit.** This study relied on survey data from thermal stress-related emergency department visits to estimate the thermal stress NEI, including the avoided death benefit, because the findings related to reduced hospitalizations did not meet the threshold of statistical rigor established for the study. However, changes in costs from hospitalizations due to thermal stress are a major contributor to thermal stress-related NEIs and have been used in previous studies conducted by team member Three[3].

3. **In undertaking future studies of this type, PAs and evaluators should be mindful that planning for – and achieving – larger Treatment and Control group sample sizes would increase statistical rigor and the validity of results, especially for NEIs associated with specific chronic illnesses or rare conditions.** Coordinating with PAs in other jurisdictions with similar climate and housing stock and active low-income programs is likely the most cost- and time-efficient way to increase statistical rigor.

4. **PAs should ensure that evaluators conducting future studies of MF or SF housing include a household income question in resident surveys.** Having self-reported income data linked to utility bill data or data from energy impact studies would facilitate program administrators in calculating program impacts on energy insecurity in their service

areas. Income data would also facilitate identifying households as moderate income for further study of this subset of the MF sector.

5. **Lack of contact information for property owners/managers and occupants is a substantial impediment to research in the MF rental sector, regardless of the income of occupants. Various steps can be taken in advance of and during research to mitigate this impediment.** The team depended on the agencies and vendors that weatherized the buildings in the study to supply the contact information for the property owners. More often than not, the information was provided only after many attempts, or was not available at all. In a few cases, it was available but not provided despite many attempts. We also depended on the property owner's assistance to gain access to residents. The following approaches could help to mitigate this impediment in future MF studies. Some of the approaches could also help with studies that include SF rental properties.

   Participating property owners/managers and occupants

   - *As part of the program application process, PAs should require – or at least request – that property owners agree in writing to provide access to the building and assist with resident outreach should their building be selected for a PA-sponsored evaluation.*

   Non-participating (control group) property owners/managers and occupants

   - Evaluators should develop a sample frame of non-participating rental property owners/managers and occupants of rental properties. This could be done by adding questions to surveys of target populations and the general population to identify the respondents' status; ask if they would be willing to participate in a future research study; and, if so, request their contact information. Non-participating rental property owners/managers could be identified by comparing these data to program records.
   - Evaluators, in combination with PA evaluation, should identify and explore opportunities to work with associations or organizations that house data of affordable multifamily buildings in the state or region of interest, in hopes of leveraging these organizations' data.
   - In the near future, the Massachusetts Office of Energy and Environmental Affairs may implement an initiative that includes collecting energy usage data at a municipal or county level. This data will help identify affordable MF properties with high energy usage.

   All occupants

   - Evaluators should ensure that future research among occupants of MF rental property include budget for in-person canvassing, especially when resident information is unavailable.

6. **Be aware of the challenge of establishing building eligibility, group assignment, and measures installed, and prepare for it in advance if possible.** We found it particularly challenging to identify weatherization status and dates, the number of units per building (for eligibility purposes), and the weatherization measures installed per building, as these weatherization agencies/vendors either did not have this information readily available, or what they had was not current.
    - PAs should encourage a broader range of low-income stakeholders to become involved in study planning as early as possible to increase the likelihood of obtaining data for participating and non-participating buildings and households.
    - PAs should encourage weatherization agencies and vendors to track participation data more comprehensively, regardless of whether or not jurisdictions outside of Massachusetts are involved. When undertaking research in concert with other jurisdictions, PAs should try to interest the PAs, weatherization agencies, and vendors in these jurisdictions to share sample frame data that includes weatherization dates and installed measures for relevant buildings from their tracking systems.
    - *Studies of the MF sector in Massachusetts could be helped by making the following modifications to program tracking systems:*
        - *The Massachusetts program data we received tracked participation by facility, not by building. Facilities can include multiple buildings. Give a unique identification number to each building, and ask that all the PAs use the same number for each building. Track the measures installed, etc., by building, not just facility.*
        - *The program data included the number of units and of buildings per facility, but not the number of units per building. Include the number of units for each building associated with each facility. This would make it easier to identify eligible buildings for study sample frames.*
7. **When conducting future studies of this type, evaluators should consider recruiting housing units directly, rather than – or in addition to – recruiting MF buildings first.** This could help avoid some of the recruitment challenges discussed above and hence reduce data collection costs. This could also improve statistical precision by reducing clustering of observations by building.
8. ***This study benefited greatly from peer review during the planning process and in the penultimate draft. PAs should consider requiring evaluators to plan for and undertake this practice in future NEI studies.***

Appendix A Detailed Monetization Approaches and Results

A.1 Use of Secondary Data

Here we describe the team's approach to selecting the secondary data used in assessing and monetizing NEIs.

The team reviewed and vetted dozens of studies and reports to identify the most relevant, recent, high-quality secondary data sources to use as monetization inputs. We also reviewed multiple databases to identify those with recent relevant information to use in monetization calculations. For example, we reviewed online databases from the U.S. DHHS, such as MEPS and HCUP; the Massachusetts Center for Health Information and Analysis (CHIA); and the National Fire Incident Reporting System. Many of these are the same secondary online databases that were used for the WAP national evaluations and the Massachusetts LISF NEI Study.

From these databases, we used the most recent available Massachusetts-specific medical expenditure data. When only national medical costs were available, we adjusted these to reflect medical costs in Massachusetts.[46] In all cases, if the medical cost data were outdated, we adjusted them to reflect medical costs for 2020.[47]

We designed a separate analytical approach for each NEI that considered how weatherization contributes to the NEI and the availability of relevant primary and secondary data.

The team used the resident survey results in most, but not all, of the selected NEIs. Two NEIs – CO poisoning and home fire prevention – are rare and difficult-to-capture events, so they are not based on resident survey findings. For these NEIs, the team reviewed and analyzed secondary data on the effectiveness of installed weatherization measures that could reduce the probability of fire (e.g., smoke detectors, repairs to electrical systems) and measure installation data collected from participating weatherization agencies (e.g., installation of CO monitors).

Estimating the monetary value of reducing hospitalizations related to thermal stress required finding secondary data on the average cost of thermal stress-related hospitalizations. We ensured that all relevant cost data for this and other NEIs were current. For example, in the case of thermal stress, we researched factors ranging from cost of medical treatment (urgent care, hospitalizations, and emergency department visits) to hourly wage rates of LI residents in Massachusetts to estimate the benefit of reducing missed days of work. When current cost data were unavailable, we applied historical costs after making adjustments to reflect 2020 prices and values.

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[46] More specifically, the Boston-Brockton-Nashua metropolitan statistical area (MSA). For more information, see: https://www.bls.gov/regions/new-england/news-release/consumerpriceindex_boston.htm
[47] Medical care price indices provided by the U.S. Bureau of Labor Statistics, http://data.bls.gov/timeseries/CUURA103SAM?data_tool=XGtable

The team rigorously explored all NEIs presented in this report for monetizable impacts. For NEIs that fit within the *theory of change* model, which requires quantifiable data from both pre- and post-weatherization groups, we gathered data for statistical analysis and produced monetary values. For NEIs that rely on installed measures data, such as CO and fire-related NEIs, we employed models and algorithms consistent with measuring changes in risk.

Prior to monetizing the NEIs, the team obtained feedback from external reviewers and the PAs on the soundness and applicability of the algorithms (within the context of the LIMF population being served in Massachusetts) and the secondary data sources and specific inputs chosen for the monetization effort.[48]

A.2 NEIs Monetized but Not Recommended for Adoption

Here, we outline the methodology we used to monetize each of the LIMF NEIs that are *not* being recommended for adoption, as well as the algorithms and data sources used for each. We present these in alphabetical order. For each NEI we also present results of questions on home livability and home conditions from the resident survey that provide supporting evidence for the monetized NEIs.

The team's starting hypothesis was that weatherization has either a positive benefit or no benefit at all, as we have not seen any indication that weatherization has a negative impact on any of the NEIs.

A.2.1 Asthma

Asthma prevalence (i.e., respondents self-reporting active asthma) for the entire LIMF population surveyed is 18.5%. The team measured the Asthma NEI using responses to asthma-related healthcare treatment questions from the resident survey. We drew these responses from surveys with all household members with reported active asthma, as well as from those who did not affirm active asthma status but reported both of the following: (1) lifetime asthma (i.e., ever been told by a healthcare professional that they have asthma) and (2) incidence estimates for treatment of asthma across the three types of healthcare settings identified below. Using the resident survey data, the team conducted a DID analysis.[49]

The team calculated means for the number of times each healthcare setting was visited to treat asthma flares, including urgent care, emergency department visits, and hospitalizations. As a first step for measuring the effect of weatherization on asthma-related outcomes, we calculated differences in means for each healthcare type reportedly used to treat asthma flares for the subsamples described above. Results from paired-samples t-tests suggest measurable changes

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[48] The preliminary Phase 1 report provided the opportunity for PAs to review the monetization algorithms and data sources.

[49] The two research groups' asthma subsamples showed differing demographics. The treatment group self-identified as Hispanic or Latino descent at higher rates than the control group, and as Black or African American at lower rates. (Just over 50% of the treatment group identified as Hispanic or Latino descent, compared to 6.5% of the control group. Nearly 29% more of the control group self-identified as Black or African American than the treatment group.) This could account for differences between the groups in asthma severity and treatment type. In addition, the control group had higher percentages of females and was older, with an average age of 55 compared to the treatment group's average age of 40.

in incidences of asthma-related healthcare encounters post-weatherization in the treatment group, but not at statistically significant levels (Table 31). The results showed post-weatherization increases in reported urgent care and hospitalizations, but decreases in emergency department visits, for the treatment group subsample. However, results for the control group suggest fewer encounters across all healthcare settings (see Table 31), and there was a statistically significant increase in encounters for urgent care encounters using DID.

It is important to consider that only 59.1% of the treatment group subsample with active asthma reported having an asthma flare-up in the last three months compared to 77.5% of the control group. This difference suggests a higher proportion of the control sample had uncontrolled asthma at baseline, possibly resulting in greater potential for this group to require urgent or emergency care for asthma-related symptoms, and possible increased responsiveness to continuous and effective maintenance of symptoms through non-urgent medical treatment.

Because the control group reported better asthma-related healthcare outcomes than the treatment group, no measurable benefit of MF weatherization on asthma can be claimed. The team reports an NEI value of zero for the Reduced Asthma NEI (Table 32) rather than a *negative* NEI value. Accounting for asthma as a negative NEI presumes that the asthma portion of this study is more definitive than this research suggests it to be.

Table 31: Resident Survey Questions – Asthma

Survey Question	T pre	T post	(+/-)	C pre	C post	DID
Do you still have asthma? (active asthma) (Yes)	16.9% (n=141)	22.0% (n=58)	NA	18.6% (n=231)	18.7% (n=124)	NA
During the past 12 months, how many times did you visit an urgent care center because of asthma? (mean)	0.14 (n=44)	1.05	+0.91	0.79 (n=111)	0.33	+1.37 (p=0.056)
During the past 12 months, how many times did you have to stay overnight in the hospital because of asthma? (mean)	0.11 (n=44)	0.14	+0.03	0.23 (n=111)	0.09	+0.16 (p=0.172)
During the past 12 months, how many times did you visit an emergency department because of asthma? (mean)	0.43 (n=44)	0.36	-0.07	0.67 (n=111)	0.18	+0.42 (p=0.126)

Table 32: Estimated Benefit for Reduced Asthma

	Annual Per Unit Benefit
Households	$0
Society	$0
Total	$0

A.2.2 Food Assistance

It is logical to contend that weatherization could have a positive enough impact on household budgets that some households on food assistance would not feel the need to apply for continued assistance post-weatherization. We observed through the resident survey that, overall, fewer households reported receiving food assistance post-weatherization (Table 33). It is possible that the direct household income benefits attributable to weatherization may allow some households to reduce their needs for food assistance payments.[50]

Table 33: Resident Survey Questions – Food Assistance

Resident Survey Question	CwT	T + C	Change
In the past 12 months did you or any members of your household receive food stamps or WIC assistance (Women, Infants, and Children nutrition program) to help pay for food?	54.9% (n=586)	59.5% (n=1252)	-4.6%✧

✧ Difference is statistically significant at the p<0.1 level.
* Difference is statistically significant at the p<.05 level.
** Difference is statistically significant at the p<.01 level.
*** Difference is statistically significant at the p<.001 level.

The team monetized the NEI for reduced need for government-subsidized food assistance using the monetization approach and inputs presented in Table 34 and Table 35, respectively.

Table 34: Monetization Approach – Food Assistance

Monetization Approach
Key Variables
• a = change in the number of HHs needing Food Assistance (%) • d = average HH size • h = average Food Assistance per person per month ($)
Equation 1. *Annual Societal Benefit (per weatherized unit)*
• *= a*d*h*12 months*

Table 35: Sources/Inputs – Food Assistance

Inputs/Sources	
Resident Survey	• Change in number of HHs needing food assistance: 4.6% • Average HH size (of those reporting food assistance): 1.42 people
Literature: Peer Reviewed and Other	• Average food assistance per person per month:[1] $126

[1] https://www.cbpp.org/sites/default/files/atoms/files/snap_factsheet_massachusetts.pdf

[50] For example, households may have enough money for food so that even if they are eligible for food assistance based on their income, they may not believe that re-applying is worth their time and/or may feel relieved at not experiencing the stigma of being on food assistance.

Table 36 presents annual estimates of the NEI Reduced Need for Food Assistance.

Table 36: Estimated Impact of Reduced Need for Food Assistance

	Annual Per Unit Benefit
Households	$0
Society	$99
Total	**$90**

A.2.3 Work Productivity

Existing literature posits that lack of sleep can negatively impact productivity. Our research findings indicate that there are reductions in reports of *poor* sleep from respondents that are weatherization recipients.

Table 37: Resident Survey Questions – Work Productivity

Survey Question	CwT	T + C	Change
During the past 30 days, for about how many days have you felt you did not get enough rest or sleep? (n=1431)	6.28 (n=468)	7.26 (n=963)	-0.98†

† p<.1

The team monetized the NEI for increased work productivity due to improved sleep using the monetization approach and inputs presented in Table 38.

Table 38: Monetization Approach – Work Productivity

Monetization Approach
Key Variables
• p = annual productivity increases attributable to better sleep and rest ($) • a = average annual salary U.S. worker ($) • d = percent change in # of days main respondents get better sleep and rest • w = value of an hour of housework • h = hours per week housework • i = productivity increase in housework (=p/a) • s = % of main respondents employed
Equation 1. *Annual Societal Benefit for Increased Work Productivity (per Wx unit)*
• = p*d*s

Table 39: Sources/Inputs – Work Productivity

Inputs/Sources	
Resident Survey	• % of main respondents employed: 23.3%
Literature: Peer Reviewed and Other	• Annual productivity increase attributable to better sleep and rest: $2,500 https://www.rand.org/pubs/research_reports/RR1791.html • Value for an hour of non-market HH production (housework): $22.80 https://www.forbes.com/sites/jennagoudreau/2011/05/02/why-stay-at-home-moms-should-earn-a-115000-salary/#5bb109f275f4 https://www.bea.gov/household-production/
Open-source Databases	• Average # of hours per week spent on housework: 21.5 hours/week • http://www.bls.gov/opub/mlr/2009/07/art3full.pdf • Average annual salary U.S. worker: https://www.census.gov/newsroom/releases/archives/income_wealth/cb12-172.html

The estimated annual impacts of increased work productivity due to improved sleep are presented in Table 40.

Table 40: Estimated Impact of Increased Work Productivity Due to Improved Sleep

	Annual Per Unit Benefit
Households	$0
Society	$17
Total	**$17**

A.2.4 Food Spoilage

It is logical to assume a direct correlation between faulty refrigerators and food spoilage. Spoiled food is a major issue for LI populations, as evidenced by findings from the resident survey. The survey results presented in Table 41 suggest that weatherization has a measurable impact on reducing the frequency of discarded food from insufficient refrigeration.

A study that looked at power outage-related expenses estimated a total of $150 billion is incurred by U.S. homeowners, annually, including the costs related to food spoilage. The 2011 study reports that, per household, an average of $160 was spent on replacing food from a power outage lasting at least 12 hours.[51]

The team hypothesized that the LI population would incur lower costs from food spoilage due to having a tighter grocery budget than the general population. We subjectively chose a conservative estimate of 50% less, resulting in an estimated average of $80 spent on replacing food after each incident. We then adjusted the $80 cost estimate for inflation from 2011 costs to 2020 costs (Table 42).

[51] https://www.aagenpro.com/often-overlooked-costs-extended-power-outage/

Table 41: Resident Survey Questions –Food Spoilage

Resident Survey Question	CwT	T + C	(+/-)
In the past 12 months how many times did you have to throw away food because your refrigerator was broken or lost power? (mean)	0.17 (n=173)	0.83 (n=37)	**-0.66**

✧ Difference is statistically significant at the p<0.1 level.
* Difference is statistically significant at the p<.05 level.
** Difference is statistically significant at the p<.01 level.
*** Difference is statistically significant at the p<.001 level.

The team monetized the NEI for reduced food spoilage using the approach and inputs presented in Table 42 and Table 43, respectively.

Table 42: Monetization Approach – Reduced Food Spoilage

Monetization Approach
Key Variables
• D = Change in # of times had to throw food away (mean)
• C$ = Average cost of food replacement per incident of Food Spoilage
Equation 1. *Total Household NEI value*
• *Total HH NEI = D * C$*

Table 43: Sources/Inputs – Reduced Food Spoilage

Inputs/Sources	
Resident Survey	• Change in # of times had to throw food away because of faulty refrigerator or loss of power: -0.66
Literature: Peer-Reviewed and Other	• Cost of food replacement per incident of food spoilage, adjusted by 50% for LI population: $80 [1,2]
Open-Source Databases	• Bureau of Labor Statistics ○ Consumer Price Index to price-adjust medical costs for MA, 2020[3]

[1] https://www.aagenpro.com/blog/often-overlooked-costs-extended-power-outage/
[2] https://www.kohlerpower.com/home/common/pdf/RES_Infographic.pdf
[3] https://data.bls.gov/timeseries/CUURS11ASAM?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

Table 44 presents the annual NEI estimates of reduced food spoilage.

Table 44: Estimated Impacts of Reduced Food Spoilage

	Annual Per Unit Benefit
Households	$57
Society	$0
Total	**$57**

A.2.5 Low-Birth-Weight Infants

The team used responses to the resident survey questions and inputs from secondary literature to determine annual household and societal savings attributable to the reduced number of low-birth-weight infants born by pregnant mothers with poor nutrition and lower levels of food insecurity. It is possible that the direct household income benefits attributable to weatherization may allow some households to increase their food security. Studies have shown that pregnant women with high food insecurity are more likely (18.7% more likely) to have low-birth-weight infants, which require more medical care in their first year of life.[52]

Table 45: Resident Survey Questions – Low-Birth-Weight Infants

Survey Question	CwT	T + C	Change
Over the past 12 months, how often has your household not purchased food in order to pay an energy bill? (% yes, at least once in 12 months)	13.1% (n=374)	21.9% (n=644)	-8.8%
In past four weeks, did you or a household member go a whole day and night without eating anything because there was not enough food? (Yes)	6.0% (n=583)	8.6% (n=1222)	-2.6%✧
In past four weeks, did you worry household members would not have enough nutritious food? (Yes)	11.8% (n=585)	14.2% (n=1232)	-2.4%
(New composite variable): Did household member say "Yes" to one or more of the above questions related to food insecurity? (Yes)[1]	**24.3% (n=387)**	**36.3% (n=697)**	**-12.0%**

[1] Created a composite variable that includes three indicators of food insecurity. Used the change in the composite variable (-12.0%) to monetize the Low-Birth-Weight Infants NEI.

✧ Difference is statistically significant at the p<0.1 level.

* Difference is statistically significant at the p<.05 level.

** Difference is statistically significant at the p<.01 level.

*** Difference is statistically significant at the p<.001 level.

[52] Borders, Ann E., William A. Grobman, Laura B. Amsden, and Jane L. Holl. "Chronic Stress and Low Birth Weight Neonates in a Low-Income Population of Women," Obstetrics & Gynecology 109, no. 2 (2007): 331-338.

The team monetized the NEI for reduced low-birth-weight infants using the monetization approach and inputs presented in Table 46 and Table 47, respectively.

Table 46: Monetization Approach – Low-Birth-Weight Infants

Monetization Approach
Key Variables
• B = Average number of infants born among the program population • C= Change in number of low-birth-weight infants (%) • D= HHs that moved from higher to lower level of food insecurity (%) • R = Reduced risk of having low-birth-weight baby if high level of food insecurity • C$ = Average medical cost resulting from care of a low-birth-weight baby
Equation 1. *Average number of Infants born among the program population*
*B = (# women of child-bearing age reported in Phase 1-Resident Survey) * (birth rate for women ages 15-44)*
Equation 2. *Change in number of low-birthweight infants (%)*
*C = D * R*
Equation 3. *Annual Societal Benefit (per weatherized unit)*
*S NEI = B * C * C$*

Table 47: Sources/Inputs – Low-Birth-Weight Infants

Inputs/Sources	
Resident Survey	• Avg. number of women of child-bearing age (15-44) per HH: (0.202) • Birth rate for women ages 15-44: (0.0628) • Percent of HHs moved from higher to lower level of food insecurity (Table 45):(12%)
Literature: Peer Reviewed and Other	• S Costs of Preterm Birth (2007): $31,290 (Birth to five years of age) plus $3,812 (Delivery)[1,2] • Chronic Stress and Low Birth Weight Neonates in a LI Population of Women (2007):[3] 18.7% reduction in risk of low-birth-weight infants for pregnant women with low versus high food insecurity
Open-Source Databases	• Bureau of Economic Analysis: Regional Price Parity to adjust national to MA price levels[4] • Bureau of Labor Statistics: Consumer Price Index to price-adjust medical costs from 2015 to 2018 dollars[5]

[1] https://www.ncbi.nlm.nih.gov/books/NBK11358/
[2] Team adjusted these costs using price indexes.
[3] https://www.ncbi.nlm.nih.gov/pubmed/17267833
[4]https://apps.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=8#reqid=70&step=1&isuri=1
[5]https://data.bls.gov/timeseries/CUURS11ASAM?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

Table 48 presents the estimated annual impacts of fewer low-birth-weight infants.

Table 48: Estimated Impact of Fewer Low-Birth-Weight Infants

	Annual Per Unit Benefit
Households	$0
Society	$10
Total	**$10**

A.2.6 Missed Days of Work

Missed days of work can negatively impact household income. The team used responses to the resident survey questions and inputs from secondary literature to determine annual household savings attributable to reduced days of work missed because of illnesses or injuries to the respondent or another person in the home.

In the results presented below, we included responses only from primary wage earners. We excluded reports of 31 or more days of missed work for the previous 12 months, as we would expect work absences of a month or more to be due to communicate disease or disability, not health issues that are responsive to weatherization.

Table 49: Resident Survey Questions – Missed Days of Work

Survey Question	CwT	T + C	Change
Mean # of missed workdays (primary wage earner) due to illness or injury for self or other HH member – last 12 mo.	3.63 (n=83)	3.16 (n=214)	-0.47

The team then used a linear regression model to estimate the impact of weatherization on missed days of work due to health of self or another household member. This model contains the weatherization *dummy* as the independent variable. In this model, the p-value (.224) is not statistically significant. We included region, size of building, gender, race, age (55+), and level of education as independent variables in the model to assess differences across the weatherized and unweatherized samples. The significance levels of the independent variables indicate that there was no statistical issue related to differences across the samples (Appendix C).

The team monetized the NEI for reduced missed days of work using the monetization approach and inputs presented in Table 50 and Table 51, respectively.

Table 50: Monetization Approach – Missed Days of Work

Monetization Approach
Key Variables
• w = average wage rate per hour for LI worker ($) • d = change in the number of missed days of work due to health of self or others (%) • e = percentage of main respondents employed • s_1 = percentage of LI workers without sick leave • s_2 = percentage of LI workers with sick leave
Equation 1. *Annual Household Benefit (per weatherized unit)*
• *= w*(8 hours)*d*e*s*
Equation 2. *Annual Societal Benefit (per weatherized unit)*
• $= w*(8\ hours)*d*e*s_2$

Table 51: Sources/Inputs – Missed Days of Work

Inputs/Sources	
Resident Survey	• Change in the number of missed days of work due to health of self or others: -0.47 days • Percentage of main respondents employed or self-employed: 23%
Literature: Peer Reviewed and Other	• Average wage rate per hour for LI workers: $12.46 http://www.massbudget.org/reports/swma/poverty.php http://www.massbudget.org/reports/swma/wages-income.php • Percentage of LI workers w/o sick leave: 77% – Bureau of Labor Statistics (2017): https://www.bls.gov/news.release/ebs2.t06.htm

Table 52 presents the estimated annual impacts of fewer missed days of work.

Table 52: Estimated Impact of Fewer Missed Days of Work

	Annual Per Unit Benefit
Households	$8
Society	$3
Total	**$11**

A.2.7 Prescription Adherence

It is possible that the direct household income benefits attributable to weatherization may allow some households to afford prescription medicines after weatherization, subsequently decreasing medical expenses. An important benefit to society for complying with physician directed prescriptions is a substantial reduction in hospitalization rates. We used responses to the resident survey questions and inputs drawn from secondary literature to determine annual societal savings attributable to improved prescription medication adherence.

Table 53: Resident Survey Questions – Prescription Adherence

Survey Question	CwT	T + C	Change
During the past 12 months, was there any time your household members needed prescription medicines but did not get them because you couldn't afford it? (n=683)	10.0% (n=)	15.4% (n=)	-5.4*

* Difference is statistically significant at the p<.05 level.

The team monetized the NEI for increased prescription adherence using the monetization approach and inputs presented in Table 54 and Table 55, respectively.

Table 54: Monetization Approach – Prescription Adherence

Monetization Approach
Key Variables
• e = annual cost to national economy due to lack of prescription medication adherence • p = U.S. population • i = % of population taking prescriptions • n = % of population non-prescription adherent • c = cost to society: lack of prescription medication adherence ($) • d = change in the percentage of HHs better able to afford prescriptions (%) • a = adjustment factor, some HHs still will not adhere to prescriptions (%)
Equation 1. *Societal Costs for Prescription Non-Adherence*
• *c = e/(p*i*n)*
Equation 2. *Annual Societal Benefit (per weatherized unit)*
• *= c*d*a*

Table 55: Sources/Inputs – Prescription Adherence

Inputs/Sources	
Resident Survey	• Change in the percentage of HHs better able to afford prescriptions: -5.4
Literature: Peer Reviewed and Other	• Annual cost to society for an individual being non-prescription adherent: http://annals.org/aim/fullarticle/1357338/interventions-improve-adherence-self-administered-medications-chronic-diseases-united-states) • % of population taking prescriptions: 70% • % of population non-prescription adherent: 50% • Cost to economy of prescription non-adherence: Cutler R. L., *et al (2018).* Economic impact of medication non-adherence by disease groups: a systematic review. *BmJ Open*; 8: e016982. doi: 10.1136/bmjopen-2017-016982. • Adjustment factor: 0.5 Liberman et al (2011). Are caregivers adherent to their own medications? Journal of the American Pharmacists Association, Volume 51, Issue 4, 492–498. https://doi.org/10.1331/JAPhA.2011.10006
Open-Source Databases	• U.S. population December 2019: 328,239,523 http://census.gov

Table 56 presents the estimated annual impacts of improved prescription adherence.

Table 56: Estimated Impact of Prescription Adherence

	Annual Per Unit Benefit
Households	$0
Society	$59
Total	**$59**

A.2.8 Short-Term High-Interest Loans

We used responses to the resident survey questions and inputs gleaned from secondary literature to determine annual household savings attributable to reduced need for taking out Short-Term, High-Interest (predatory) loans due to improved budget situations (e.g., from reduced energy costs or decreased medical expenses).

Table 57: Resident Survey Questions – Short-Term Loans

Survey Question	T+C	CwT	Change
***In the past year, have you used any of the following to assist with paying your energy bill?* (n=355)**			
Payday loan	0.039	0.022	-0.017
Tax refund anticipation loan	0.019	0.017	-0.002
Car title loan	0.005	0.007	+0.002
Other type of short term, high-interest loan	0.023	0.015	-0.008
Pawn shop	0.056	0.047	-0.009

The team monetized the NEI of the reduced use of short-term, high-interest loans using the monetization approach and inputs presented in Table 58 and Table 59, respectively.

Table 58: Monetization Approach – Short Term Loans

Monetization Approach
Key Variables
For each loan type (a); payday, tax refund, car title, other, pawn • I = average interest payment per loan (a) ($) • d = change in # of loans assumed by HHs (mean)
Equation 1. *Annual Household Benefit (per weatherized unit)*
• *= I * d (for every loan type a)* • *NEI = 0.017*$90 + 0.0102*$35 + (-0.002)*$250 + 0.008* $119 + 0.009*$30*

Table 59: Sources/Inputs – Short Term Loans

Inputs/Sources	
Resident Survey	• Change in the # of loans assumed by HHs by loan type (a)
Literature: Peer Reviewed and Other	• Federal Deposit Insurance Corporation (2015). National Survey of Unbanked and Underbanked Households.[1] • Neil Bhutta, Jacob Goldin, Tatiana Homono (2015). Consumer Borrowing After Payday Loan Bans. • The Pew Charitable Trusts (2015). Auto Title Loans: Market practices and borrowers' experiences.[2] • Consumer Financial Protection Bureau (2013).[3] • Robert B. Avery (2011). Payday Loans versus Pawnshops: The Effects of Loan Fee Limits on HH Use.

[1] https://www.fdic.gov/householdsurvey/2015/2015report.pdf
[2] http://www.pewtrusts.org/~/media/assets/2015/03/autotitleloansreport.pdf
[3] https://files.consumerfinance.gov/f/201304_cfpb_payday-factsheet.pdf

Table 60 presents the estimated annual impacts of reduced use of short-term, high-interest loans.

Table 60: Estimated Impact of Reduced Use of Short-Term, High-Interest Loans

	Annual Per Unit Benefit
Households	$2
Society	$0
Total	**$2**

A.2.9 Trips and Falls

Adults aged 65 and older are at greater risk of falling in their dwellings compared to the general population, and the resulting medical costs increase with age.[53] According to the Centers for Disease Control and Prevention (CDC), the medical costs associated with trips and falls in this age group were estimated at over $50 billion nationally in 2015. [54] Given the advanced mean age of the study population, trips and falls pose a serious concern for many program recipients. The CDC[55] and the National Safety Council[56] recommend installing good lighting, stair handrails, and shower grab bars to prevent trips and falls in the home.[57] Because lighting improvements are often included in weatherization as energy conservation measures and fall prevention measures, and are at times considered allowable incidental health and safety repairs,[58] there is reason to believe weatherization can reduce the rate of trips and falls requiring medical attention.

The results indicated a decrease in incidences of trips and falls inside common areas of weatherized apartment buildings that produced 30.3% fewer visits to the doctor's office. This difference is statistically significant (Table 61). The team used this input for monetizing the Trips and Falls NEI (Table 62). Note that the Comparison-with-Treatment group reported fewer urgent care medical encounters than the unweatherized (T_Pre+C) group for trips and falls in common areas, though not at a statistically significant level. Between the lack of statistical significance and the low likelihood of weatherization causing trips and falls, we report a $0 benefit for the urgent care medical encounters. The survey results for trips and falls that occurred inside *apartment units*, shown in Table 61, were unexpected. The Comparison-with-Treatment homes group reported a higher number of medical encounters than the T+C group. Interestingly, 80% of units received some type of lighting upgrade, although none of the agencies reported any type of incidental repairs or installation of fall-avoidance measures.

One potential explanation for the higher incidence in reported trips and falls among the Comparison-with-Treatment group is that the average age of the Comparison-with-Treatment group was higher than that of the Treatment+Control group by a statistically significant amount. Assuming older individuals are more prone to trips and falls than younger individuals, one might reasonably hypothesize a higher trip and fall rate in the Comparison-with-Treatment group. An additional factor to consider is the slightly higher prevalence of women in the Comparison-with-Treatment group. In one peer-reviewed article, women were roughly 20% more likely to be hospitalized and 10% more likely to visit an emergency department than men when they needed

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[53] Elizabeth R. Burns, Judy A. Stevens, Robin Lee. The direct costs of fatal and non-fatal falls among older adults – United States, J of Safety Res, Vol. 58, 2016, pgs 99-103. https://doi.org/10.1016/j.jsr.2016.05.001.

[54] https://www.cdc.gov/homeandrecreationalsafety/falls/adultfalls.html

[55] Centers for Disease Control and Prevention, 2017. Important Facts About Falls, 2017. Retrieved accessed 19 June 19, 2018 from: https://www.cdc.gov/homeandrecreationalsafety/falls/adultfalls.html

[56] National Safety Council. 2018. Fall-prevention Measures Can Keep Older Adults Independent. Retrieved accessed 19 June 19, 2018 from: https://www.nsc.org/home-safety/safety-topics/older-adult-falls

[57] https://www.cdc.gov/steadi/pdf/check_for_safety_brochure-a.pdf
https://www.nsc.org/home-safety/safety-topics/older-adult-falls

[58] Not all LI weatherization agency programs are able to provide incidental health and safety repairs for their clients. Some programs that do can include fall prevention measures as an allowable health and safety measure.

medical attention for a fall.[59] However, men were 37% more likely to go to a doctor's office or urgent care when needing medical care for a fall.[60]

The team does not report in-unit lighting as an outcome of MF weatherization.

Table 61: Resident Survey Questions – Trips and Falls

Resident Survey Question (all persons: n=57)	CwT	T + C	Change
For those that reported needing medical care for a trip or fall inside <u>common areas</u> of apartment building, what types of medical attention did that individual seek?			
Non-Urgent Care [1]	5.6%	35.9%	-30.3%**
Urgent Care	16.7%	5.1%	+11.6%
Emergency Department	61.1%	59.0%	+2.1
Hospital	27.5%	20.5%	+7.0%
For those that reported needing medical care for a trip or fall inside their <u>apartment unit</u>, what types of medical attention did that individual seek?			
Non-Urgent Care	32.6%	27.9%	+4.7%
Urgent Care	30.4%	6.6%	+23.8%**
Emergency Department	50.0%	61.3%	-11.3%
Hospital	19.6%	30.6%	-11.0%

[1] Used as monetization input for Trips and Falls NEI.
** Difference is statistically significant at the p<.01 level.

The team monetized the NEI for reduced trips and falls using the monetization approach and inputs presented in Table 62 and Table 63, respectively.

Table 62: Monetization Approach - Trips and Falls

Key Variables

- C$ = average cost of non-urgent medical treatment for a trip or fall inside the building
- T_{pre} = number of trips and falls resulting in non-urgent medical treatment
- T_{post} = number of trips and falls resulting in non-urgent medical treatment
- S$ = cost impact per weatherized unit related to non-urgent medical treatment
- TS$ = total impact per weatherized unit

Equation 1. *Annual Impact (per weatherized unit)*

- S$ = [((C$*$T_{post}$) / number of pre-weatherization HHs) - ((C$*$T_{pre}$) / number of post-weatherization HHs)]

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[59] Elizabeth R. Burns, Judy A. E., Stevens, J., Robin Lee, R. "The direct costs of fatal and non-fatal falls among older adults – United States," Journal of Safety Research 58 (2016). The direct costs of fatal and non-fatal falls among older adults – United States, J of Safety Res, Vol. 58, pgs: 99-103., accessed April 1, 2019, https://doi.org/10.1016/j.jsr.2016.05.001.
[60] Ibid.

Table 63: Sources/Inputs – Trips and Falls

Inputs/Sources	
Resident Survey	• Change in incidences of trips and falls in common areas of building resulting in non-urgent care (-30.3%)
Open-Source Databases	• Average cost of non-urgent medical treatment for a trip or fall[1] • Bureau of Economic Analysis[2] ○ Regional Price Parity to adjust national to MA price levels • Bureau of Labor Statistics: ○ Consumer Price Index to price-adjust medical costs from 2015 to 2020 dollars

[1] Elizabeth R. Burns, Judy A. Stevens, Robin Lee. The direct costs of fatal and non-fatal falls among older adults – United States, J of Safety Res, Vol. 58, 2016, pgs. 99-103. https://doi.org/10.1016/j.jsr.2016.05.001.
[2] https://www.bea.gov/

Table 64 presents the estimated annual impacts of fewer trips and falls.

Table 64: Estimated Impact of Fewer Trips and Falls

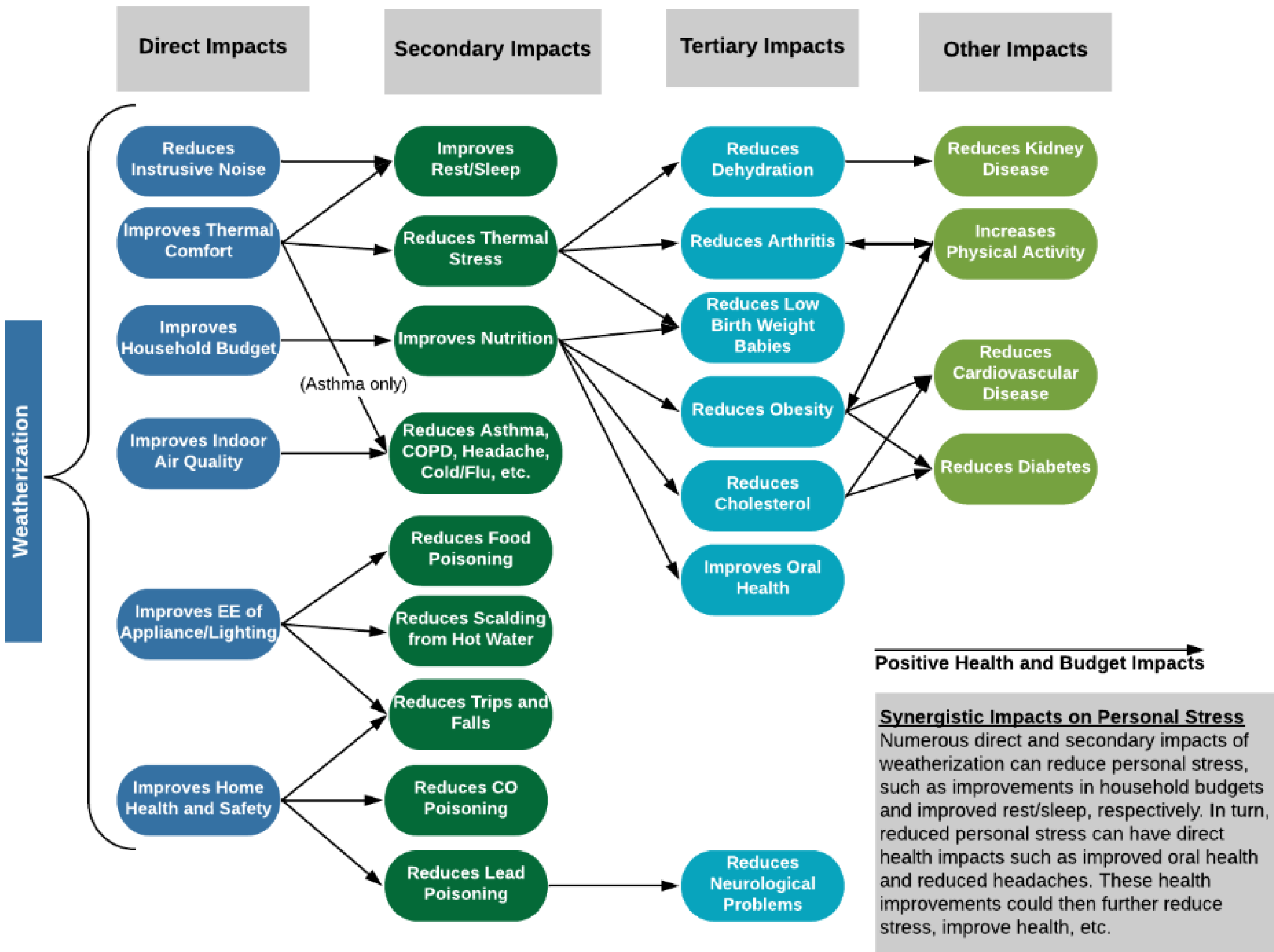
	Annual Per Unit Benefit
Households	$3
Society	$46
Total	**$49**

Appendix B Additional LIMF NEIs to Consider

Research into the potential health and household-related NEIs of LI weatherization continues to evolve. The work undertaken in this, and the JPB study, are at the forefront of research exploring new NEIs to consider monetizing.

Figure 2 presents a more detailed depiction of the relationships between weatherization and its direct, secondary, and tertiary impacts on health than the graphic presented in Section 1.2.1. The figure posits that improvements in household budgets can lead to improvements in nutrition as fewer households report trading-off buying food to pay their utility bills. Improved nutrition can lead to reduced obesity and improved overall health. In addition, improved thermal performance can reduce indoor thermal stress, which can reduce arthritis symptoms via decreased pain. Decreased pain could spur individuals to increase their physical activity. These impacts can, in turn, synergistically and positively impact cholesterol levels. Lastly, as the figure shows, the relationships between weatherization and psychosocial stress are complex. A few of the direct impacts of weatherization can also directly reduce individuals' stress levels. For example, reducing energy costs can reduce challenges surrounding household budgets, which can improve both quality of life and general health. Improvements in health, which range from decreased thermal stress to feeling more rested and sleeping better, can also reduce psychosocial stress. Reductions in mental stress can have beneficial physical health impacts, such as reducing headaches, improving sleep, or reducing stress hormone levels, thereby improving cardiovascular health.

Figure 2: Relationships Between Weatherization and Health Benefits



The resident survey contains questions to support the consideration of an additional 17 NEIs. In the remainder of this appendix, we identify NEIs we consider promising for future monetization studies, based on two factors: (1) likely strong evidence of change pre- to post-weatherization, and (2) likely magnitude of the NEI. Here, we identify these additional health-and household-related NEIs. Developing robust analytical and monetization approaches for these NEIs was beyond the scope of this study. The team presents strong initial results of statistical analysis, but not does not present NEI values.

Table 65 shows the NEIs to consider for future monetization, with justification. Table 66 shows a list of additional NEIs to consider for future exploration and notes potential challenges to monetizing these NEIs.

Table 65: NEIs to Consider for Future Monetization

NEI	Justification for Future Monetization
CVD	Sound theory of change; results of statistical analysis are promising
Headaches	Sound theory of change; initial results of statistical analysis are promising
Energy assistance	Sound theory of change; initial results of statistical analysis are promising
Noise pollution	Sound theory of change; strong initial results of statistical analysis
Mental health and well-being	Sound theory of change; strong initial results of statistical analysis
Refrigerated medicines	Initial statistical results suggest this is an important issue for MF population and could have a high monetary benefit; however, the weatherization may not impact this NEI
Electrical medical equipment	Initial statistical results suggest this is an important issue for MF population and could have a high monetary benefit; however, the weatherization may not impact this NEI
Residential instability	Sound theory of change (re thermal conditions); initial results are promising

Table 66: NEIs to Consider for Future Exploration

NEI	Potential Challenges to Monetization
Burns from water	Likely lack of evidence of change
Disconnect notices	Potential double counting at HH level; already claimed by PAs at utility level
Disconnections	Potential double counting at HH level; already claimed by PAs at utility level
Food poisoning	Likely lack of evidence of change
Lead poisoning	Programs infrequently address lead issues
Missed days of school	Likely lack of evidence of change

The rest of this appendix presents descriptive statistics for the NEIs listed above, grouped by topic (i.e., health and well-being, safety, dwelling quality, and budget issues). Table 67 through Table 80 show the resident survey findings on which we based the likelihood of monetization.

B.1 ADDITIONAL HEALTH-RELATED NEIs

Lead poisoning is a significant public health issue. It can be addressed, in part, through lead remediation of homes and buildings. Lead remediation is not part of the MF weatherization program in MA.

Table 67: Resident Survey Questions – Lead Poisoning

Resident Survey Question	CwT	T + C	(+/-)
Has anyone in the household ever experienced lead poisoning? (Yes) (n=2698)	0.2% (n=828)	0.5% (n=1870)	-0.3%

Poor mental health is a major health issue in the U.S. Weatherization can lead to improvements in mental health by reducing stress about bills; improving home comfort; reducing the intrusion of outdoor noise; and reducing other irritants, such as odors and pests. The survey results presented in the table immediately below suggest that weatherization may have a measurable impact on mental health.

Table 68: Resident Survey Questions – Mental Health and Well Being

Resident Survey Question	CwT	T + C	(+/-)
Thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good? (mean) (n=1411)	4.72 (n=464)	5.64 (n=947)	-0.93 †
During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation? (mean) (n=1397)	4.28 (n=461)	4.49 (n=936)	-0.21

† p<0.1

Cardiovascular disease (CVD) is another major health issue that afflicts U.S. citizens. The team hypothesized that weatherization could reduce symptoms of CVD by improving home comfort and IAQ. For example, if symptoms of arthritis are lessened, individuals are better able to be mobile or more active, which could also reduce CVD symptoms. The survey results reported immediately below are promising, though the questions themselves are not phrased to directly explore whether respondents have heart disease.

Table 69: Resident Survey Questions – CVD

Resident Survey Question	CwT	T + C	(+/-)
When engaged in moderate activity, your heart beats faster than normal; you can talk but not sing. Examples include fast walking, aerobics class, doing weights, or swimming gently. *How many days per week do you do moderate physical activities for at least 30 minutes? (mean) (n=1501)*	2.86 (n=482)	2.93 (n=1019)	-0.07
When engaged in vigorous activity, your heartbeat increases a lot, you can't talk, or your talk is broken up by large breaths. Examples include jogging, running, basketball, or hiking up a steep hill. *How many days per week do you do vigorous physical activities for at least 20 minutes*? *(mean) (n=1389)*	1.40 (n=442)	1.63 (n=947)	-0.23 †

† p<0.1

Headaches are a source of discomfort for many Americans. Weatherization can reduce the incidence of headaches by improving home comfort, reducing the intrusion of outdoor noise, improving indoor lighting, and reducing stress. The survey results presented in Table 70 suggest that weatherization may have a measurable impact on headaches.

Table 70: Resident Survey Questions – Headaches

Resident Survey Question	CwT	T + C	(+/-)
In the past three months, have you had headaches that are either new or more frequent or severe than ones you have had before? (Yes) (n=695)	18.2% (n=587)	22.2% (n=1244)	-2.0%†

† p<0.1

Weatherization can reduce the incidence of burns from hot water simply by reducing the temperature to which water is heated. However, the initial survey results suggest that this issue is fairly rare (Table 71).

Table 71: Resident Survey Questions – Burns from Hot Water

Resident Survey Question	CwT	T + C	(+/-)
In the past 12 months, did anyone in the household see a medical professional because of burns from scalding hot water coming out of a faucet or showerhead inside your home? (Yes) (n=1846)	0.2% (n=590)	0.2% (n=1256)	0%

Weatherization can reduce the number of days that students miss school by improving student health and the health of their care givers. However, the initial survey results do not support this hypothesis (Table 72).

Table 72: Resident Survey Questions – Missed Days of School

Resident Survey Question	CwT	T + C	(+/-)
In the past 12 months, how many days of preschool has this child missed due to illness? (mean) (n=29)	7.85(n=7)	4.50 (n=22)	+3.36†
In the past 12 months, how many days of school has this child missed due to illness? (mean) (n=130)	5.35 (n=34)	5.40 (n=94)	-0.05

† $p<0.1$

The team hypothesized that weatherization could reduce the incidence of food poisoning by replacing inefficient, malfunctioning refrigerators. The survey results suggest that food poisoning is a rare event and the initial results do not support the hypothesis (Table 73).

Table 73: Resident Survey Questions – Food Poisoning

Resident Survey Question	CwT	T + C	(+/-)
In the past 12 months, did anyone in the household see a medical professional for food poisoning because your refrigerator was not at a temperature that was safe for food? (Yes) (n=1844)	0.9% (n=587)	1.0% (n=1257)	-0.1%

B.2 Additional Safety-Related NEIs

The results presented in Table 74 indicate that a sizable proportion of households have someone who relies on electrical medical equipment, and over one-half report that it would be life threatening to them if the equipment were unpowered for an extended period. Because of the importance of this equipment to this population, this NEI warrants further consideration (though it is also the case that weatherization may not directly reduce power outages to units).

Table 74: Resident Survey Questions – Electrical Medical Equipment

Resident Survey Question	CwT	T + C	(+/-)
Do you or does anyone else in your household rely on medical equipment that would stop working if the power goes out? (Yes) (n=1771)	14.1% (n=560)	14.0% (n=1211)	NA
Would it be life threatening if your electric medical equipment was unable to be powered for an extended period? (Yes) (n=219)	55.2% (n=67)	66.4% (n=157)	NA

Table 75 indicates that a sizable proportion of households have someone who relies on refrigerated medicines and just under one-half report that it would be life threatening to them if their medicines were unrefrigerated for an extended period. Because of the importance of this equipment to this population, this NEI warrants further consideration.

Table 75: Resident Survey Questions – Refrigerated Prescriptions

Resident Survey Question	CwT	T + C	(+/-)
Do you or anyone else in your household take prescription medicines that need to be kept in the refrigerator? (Yes) (n=1836)	17.4% (n=579)	15.6% (n=1257)	+1.8%
Would it be life threatening if the medicines were not refrigerated for an extended period because of a power outage? (Yes) (n=235)	48.1% (n=81)	44.8% (n=154)	+3.3%

B.3 Additional Dwelling Quality-Related NEIs

Noise is a problem that is endemic to urban areas in the U.S. Weatherization can reduce the stress from the intrusion of noise into apartment units through insulation and air sealing and repairing and replacing broken windows and doors. The survey results in Table 76 strongly suggest that weatherization may have a measurable impact on noise.

Table 76: Resident Survey Questions – Noise

Resident Survey Question	CwT	T + C	(+/-)
How much outdoor noise do you hear indoors when the windows are closed? (a great deal or some) (n=1846)	52.0% (n=586)	62.7% (n=1260)	-10.7%***
Thinking about the past 12 months, how much of this outdoor noise interfere with your sleep at night? (Extremely, very much, or moderately) (n=1536)	22.7% (n=471)	28.1% (n=1065)	-5.4%*
How much does outdoor noise bother, disturb, or annoy you when you are inside your apartment? (moderately or great deal) (n=1648)	26.7% (n=535)	33.2% (n=1113)	-6.5%**

✧ Difference is statistically significant at the p<0.1 level.
* Difference is statistically significant at the p<.05 level.
** Difference is statistically significant at the p<.01 level.
*** Difference is statistically significant at the p<.001 level

Odors seeping in from outdoors and adjacent units also negatively impact apartment dwellers. Weatherization can reduce odors through air sealing and insulation and improving ventilation. The survey results in Table 77 strongly suggest that weatherization may have a measurable impact on odors. This NEI could be considered an indicator of other NEIs, such as improved well-being, rather than its own NEI. A decrease in frequency of chronic headaches may be correlated with a decrease in odors.[61]

Table 77: Resident Survey Questions – Odors

Resident Survey Question	CwT	T + C	(+/-)
How often do you smell odors from outside your home when the windows are closed? (very or fairly often) (n=1905)	13.3% (n=607)	21.7% (n=1298)	-8.4%***
How often do you smell odors from other apartments or the hallway when you are inside your apartment? (very or fairly often) (n=1613)	23.8% (n=529)	28.0% (n=1084)	-4.2%✧

✧ Difference is statistically significant at the p<0.1 level.
* Difference is statistically significant at the p<.05 level.
** Difference is statistically significant at the p<.01 level.
*** Difference is statistically significant at the p<.001 level

B.4 Additional Budget-Related NEIs

Residential instability is a serious problem for LI renters across the U.S. The team hypothesizes that weatherization could reduce the probability of situations that could force households to temporarily move out of their apartments. The survey results presented in Table 78 suggest that weatherization may have a measurable impact on residential instability by preventing dwellings from being uninhabitable because they are too hot or cold.

Table 78: Resident Survey Questions – Residential Instability

Resident Survey Question	CwT	T + C	(+/-)
In the past 12 months, did you have to temporarily move out of your apartment because of any of the following reasons: (Yes)			
Did not have power	1.4% (n=588)	1.9% (n=1273)	-0.5%
Flooding	0.7% (n=588)	0.7% (n=1272)	0.0%
Fire	0.2% (n=588)	0.1% (n=1272)	+0.1%
Apartment too hot	0.5% (n=588)	1.3% (n=1272)	-0.8%
Apartment too cold	0.7% (n=588)	1.4% (n=1272)	-0.7%

61 https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Hope-Through-Research/Headache-Hope-Through-Research

Weatherization can directly lead to reduced needs for energy assistance by making energy bills easier to afford. This benefit accrues to society (e.g., government energy assistance programs, friends, and family), not individual households. The survey results in Table 79 suggest that weatherization may have a measurable impact on energy assistance.

Table 79: Resident Survey Questions − Energy Assistance

Resident Survey Question	CwT	T + C	(+/-)
Some agencies offer assistance with paying for energy bills. Did your household receive energy assistance this year? (Yes) (n=1012)	34.0% (n=365)	36.6% (n=647)	-2.6%

Weatherization can directly lead to reduced disconnection notices and disconnections by making energy bills easier to afford. This benefit can accrue to both households and the utilities. The team has not monetized these NEIs because of potential double-counting at the household level and because the PAs already claim this benefit from the ratepayers' perspective.

Table 80: Resident Survey Questions – Disconnect Notices and Disconnections

Resident Survey Question	CwT	T + C	(+/-)
When home energy bills are not paid on time, it is common for energy utilities and suppliers to send late notices. During the past 12 months, how often did you receive a disconnect, shut-off, or non-delivery notice? (almost every month or some months) (n=935)	9.3% (n=343)	12.2% (n=592)	-2.9%
In the past 12 months, was your electricity or natural gas ever disconnected because you were unable to pay your home energy bill? (Yes) (n=1066)	1.8% (n=386)	4.6% (n=680)	-2.8%*
While your electricity or natural gas was disconnected, was there a time when you wanted to use your main source of heat but were unable to? (Yes) (n=34)	60.0% (n=5)	37.9% (n=29)	+22.1%
While your electricity was disconnected, was there a time when you wanted to use your air conditioner but were unable to? (Yes) (n=36)	50.0% (n=6)	36.7% (n=30)	+13.3%

* Difference is statistically significant at the p<.05 level.

Appendix C Regression Analysis Results

Figure 3 through Figure 9 contain detailed outputs from all regression models explored. The bullets below describe the independent variables that were statistically significant.

- The size of the building (number of units) indicator variable was statistically significant in the medical encounters (emergency department and doctor's office visits) for Thermal Stress (Cold) models.
- The age variable was statistically significant in all models except emergency department visits for Thermal Stress (Cold) hospitalizations for Thermal Stress (Hot) and number of missed days of work due to illness or injury.
- The education, race (Black/African American = 1), and gender (male = 1) variables were all statistically significant in the bad days of rest/sleep model for the Home Productivity NEI.

Figure 3: Arthritis Hospitalizations – Regression Analysis Parameters and Results

Key coefficient / estimate of Δ

- Beta coefficient from regression estimate = -.074

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.220	.067		3.296	.001
	PrePostGroups	-.074	.044	-.060	-1.674	.094
	region_MW	.011	.049	.009	.224	.823
	# of Units in Building	.000	.000	-.017	-.457	.648
	HSorLess	.023	.040	.020	.591	.555
	age55	-.145	.059	-.084	-2.456	.014
	RESPONDENT GENDER	.038	.047	.028	.810	.418
	race_black	.063	.051	.048	1.237	.217

a. Dependent Variable: How many different times were you admitted to a hospital in the past 12 months because of your arthritis?

Dependent variable

- Number of arthritis related hospitalizations

Independent variables

- Weatherization indicator [CwT - (T+C)] "PrePostGroups"
- Region indicator (Midwest)
- Size of building (# of units)
- Education indicator (HS Diploma/GED or less)
- Respondent age indicator (55+)
- Gender indicator (Male)
- Race indicator (Black)

Dataset characteristics

- Regression performed on Phase 1 household level data – using [T + C] for pre-weatherization group and [CwT] for post-weatherization group

Sample Size (n)

- # in the model = 877

Significance (regression)

- R^2 = .018
- p-value = .094

Figure 4: Thermal Stress (Cold) Emergency Department and Doctor's Office Visits – Regression Analysis Parameters and Results

Key coefficient / estimate of Δ

- Beta coefficient from regression estimate (ED visits - cold) = -.020
- Beta coefficient from regression estimate (doc visits - cold) = -.032

Model 1

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.026	.009		3.003	.003
	PrePostGroups	-.020	.008	-.053	-2.638	.008
	region_MW	.004	.008	.011	.508	.612
	# of Units in Building	.000	.000	-.042	-2.074	.038
	HSorLess	.001	.007	.002	.110	.913
	age55	.004	.007	.012	.587	.557
	Gender	.001	.007	.004	.183	.855
	race_black	-.001	.008	-.002	-.073	.942

a. Dependent Variable: Number of times went to EMERGENCY ROOM: COLD

Model 2

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.081	.014		5.822	.000
	PrePostGroups	-.032	.012	-.053	-2.645	.008
	region_MW	-.013	.013	-.023	-1.022	.307
	# of Units in Building	.000	.000	-.036	-1.761	.078
	HSorLess	.000	.011	.000	.017	.987
	age55	-.032	.011	-.056	-2.803	.005
	Gender	-.013	.011	-.023	-1.181	.238
	race_black	.008	.013	.014	.647	.518

a. Dependent Variable: Number of times went to DOCTORS OFFICE: COLD

Dataset characteristics

- Regression performed on Phase 1 person-level data – using [T + C] for pre-weatherization group and [CwT] for post-weatherization group

Sample Size (n)

- # in the model: 2,887

Significance (ED Visits)

- R^2 = .003
- p-value = **.008**

Significance (Doc Visits)

- R^2 = .009
- p-value = **.008**

Dependent variable

- Number of thermal stress – cold-related ED visits (Model 1)
- Number of thermal stress – cold-related doctor's office visits (Model 2)

Independent variables (same for Model 1 & Model 2)

- Weatherization indicator [CwT - (T+C)] "PrePostGroups"
- Region indicator (Midwest)
- Size of building (# of units)
- Education indicator (HS Diploma/GED or less)
- Respondent age indicator (55+)
- Gender indicator (Male)
- Race indicator (Black/African American)

Figure 5: Thermal Stress (Cold and Heat) Hospitalizations – Regression Analysis Parameters and Results

Key coefficient / estimate of Δ

- Beta coefficient from regression estimate (Hosp - cold) = -.010
- Beta coefficient from regression estimate (Hosp - hot) = -.002

Model 1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.013	.010		1.315	.189
	PrePostGroups	-.010	.009	-.022	-1.121	.262
	region_MW	-.009	.009	-.023	-1.046	.295
	# of Units in Building	-4.424E-5	.000	-.012	-.596	.551
	HSorLess	-.003	.008	-.007	-.355	.722
	age55	.022	.008	.054	2.696	.007
	Gender	.001	.008	.002	.083	.934
	race_black	.007	.009	.017	.757	.449

a. Dependent Variable: Number of times stayed overnight in the HOSPITAL: COLD

Model 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.003	.005		.724	.469
	PrePostGroups	-.002	.004	-.012	-.611	.542
	region_MW	.004	.004	.020	.915	.360
	# of Units in Building	2.124E-5	.000	.013	.622	.534
	HSorLess	-.001	.004	-.004	-.233	.816
	age55	.001	.004	.006	.276	.782
	Gender	-.003	.004	-.017	-.884	.377
	race_black	.002	.004	.012	.547	.584

a. Dependent Variable: Number of times stayed overnight in the HOSPITAL: HOT

Dataset characteristics

- Regression performed on Phase 1 person-level data – using [T + C] for pre-weatherization group and [CwT] for post-weatherization group

Sample Size (n)

- # in the model: 2,887

Significance (Hosp - cold)

- R^2 = .003
- p-value = .262

Significance (Hosp - hot)

- R^2 = .002
- p-value = .542

Dependent variable

- Number of thermal stress – cold hospitalizations (Model 1)
- Number of thermal stress – hot hospitalizations (Model 2)

Independent variables (same for Model 1 & Model 2)

- Weatherization indicator [CwT - (T+C)] “PrePostGroups”
- Region indicator (Midwest)
- Size of building (# of units)
- Education indicator (HS Diploma/GED or less)
- Respondent age indicator (55+)
- Gender indicator (Male)
- Race indicator (Black/African American)

Figure 6: Thermal Stress (Heat) Emergency Department and Doctor's Office Visits – Regression Analysis Parameters and Results

Key coefficient / estimate of Δ

- Beta coefficient from regression estimate (ED visits - hot) = +.007
- Beta coefficient from regression estimate (doc visits - hot) = -.003

Model 1

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.002	.007		.237	.813
	PrePostGroups	.007	.006	.023	1.151	.250
	region_MW	.017	.006	.058	2.628	.009
	# of Units in Building	-4.021E-6	.000	-.002	-.076	.940
	HSorLess	3.709E-5	.005	.000	.007	.995
	age55	.005	.006	.019	.930	.353
	Gender	-.009	.006	-.029	-1.533	.125
	race_black	.000	.007	-.001	-.028	.978

a. Dependent Variable: Number of times went to EMERGENCY ROOM: HOT

Model 2

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.015	.006		2.527	.012
	PrePostGroups	-.003	.005	-.011	-.562	.574
	region_MW	.007	.005	.029	1.318	.188
	# of Units in Building	-2.515E-5	.000	-.011	-.558	.577
	HSorLess	-.007	.005	-.027	-1.425	.154
	age55	.000	.005	-.001	-.062	.950
	Gender	-.002	.005	-.007	-.358	.720
	race_black	.000	.006	-.001	-.049	.961

a. Dependent Variable: Number of times went to DOCTORS OFFICE: HOT

Dataset characteristics

- Regression performed on Phase 1 person-level data – using [T + C] for pre-weatherization group and [CwT] for post-weatherization group

Sample Size (n)

- # in the model: 2,887

Significance (ED Visits)

- R^2 = .004
- p-value = .250

Significance (Doc Visits)

- R^2 = .002
- p-value = .574

Dependent variable

- Number of thermal stress – hot-related ED visits (Model 1)
- Number of thermal stress – hot-related doctor's office visits (Model 2)

Independent variables (same for Model 1 & Model 2)

- Weatherization indicator [CwT - (T+C)] "PrePostGroups"
- Region indicator (Midwest)
- Size of building (# of units)
- Education indicator (HS Diploma/GED or less)
- Respondent age indicator (55+)
- Gender indicator (Male)
- Race indicator (Black/African American)

Figure 7: Home Productivity – Regression Analysis Parameters and Results

Key coefficient / estimate of Δ

- Beta coefficient from regression estimate = -1.151

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	10.179	.693		14.697	<.001
	PrePostGroups	-1.151	.560	-.058	-2.054	.040
	region_MW	.912	.580	.048	1.573	.116
	# of Units in Building	-.008	.005	-.046	-1.590	.112
	age55	-1.437	.563	-.070	-2.553	.011
	HSorLess	-1.511	.494	-.081	-3.059	.002
	Respondent gender	-1.798	.538	-.092	-3.345	<.001
	race_black	-1.214	.605	-.061	-2.005	.045

a. Dependent Variable: During the past 30 days, for about how many days have you felt you did not get enough rest or sleep?

Dependent variable

- During the past 30 days, for about how many days have you felt you did not get enough rest or sleep?

Independent variables

- Weatherization indicator [CwT - (T+C)] "PrePostGroups"
- Region indicator (Midwest)
- Size of building (# of units)
- Respondent age indicator (55+)
- Education indicator (HS Diploma/GED or less)
- Gender indicator (Male)
- Race indicator (Black/African American)

Dataset characteristics

- Regression performed on Phase 1 person-level data – using [T + C] for pre-weatherization group and [CwT] for post-weatherization group

Sample Size (n)

- # in the model = 1,431

Significance

- R^2 = .029
- p-value = .040

Figure 8: Food Spoilage – Regression Analysis Parameters and Results

Key coefficient / estimate of Δ

- Beta coefficient from regression estimate = .050

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.514	.122		4.202	.000
	31_fridge_installed	.050	.087	.032	.579	.563
	region_MW	-.190	.119	-.096	-1.600	.111
	# of Units in Building	-.002	.001	-.063	-1.139	.255
	age55	-.294	.108	-.151	-2.725	.007
	Respondent gender	.112	.101	.060	1.101	.272
	race_black	.067	.126	.031	.532	.595

a. Dependent Variable: In the past 12 months how many times did you have to throw away food because your refrigerator was broken or lost power?

Dependent variable

- In the past 12 months how many times did you have to throw away food because your refrigerator was broken or lost power?

Independent variables

- Weatherization indicator [CwT - (T+C)] "PrePostGroups"
- Region indicator (Midwest)
- Size of building (# of units)
- Education indicator (HS Diploma/GED or less)
- Respondent age indicator (55+)
- Gender indicator (Male)
- Race indicator (Black/African American)

Dataset characteristics

- Regression performed on Phase 1 person-level data – using [T + C] for pre-weatherization group and [CwT] for post-weatherization group

Sample Size (n)

- # in the model = 1,627

Significance

- R^2 = .032
- p-value = .563

Figure 9: Missed Days of Work – Regression Analysis Parameters and Results

Key coefficient / estimate of Δ

- Beta coefficient from regression estimate = -1.019

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	4.303	.859		5.007	.000
	PrePostGroups	-1.019	.836	-.075	-1.219	.224
	region_MW	-.378	.837	-.031	-.451	.652
	# of Units in Building	-.004	.007	-.040	-.616	.539
	HSorLess	-.755	.718	-.062	-1.051	.294
	age55	.097	.739	.008	.132	.895
	Respondent gender	.180	.842	.013	.213	.831
	race_black	-.517	.856	-.042	-.604	.546

a. Dependent Variable: In the past 12 months, about how many days of work did the primary wage earner miss because of illness or injury? .

Dependent variable

- In the past 12 months, about how many days of work did the primary wage earner miss because of illness or injury

Independent variables

- Weatherization indicator [CwT - (T+C)] "PrePostGroups"
- Region indicator (Midwest)
- Size of building (# of units)
- Education indicator (HS Diploma/GED or less)
- Respondent age indicator (55+)
- Gender indicator (Male)
- Race indicator (Black/African American)

Dataset characteristics

- Regression performed on Phase 1 person-level data – using [T + C] for pre-weatherization group and [CwT] for post-weatherization group

Sample Size (n)

- # in the model = 303

Significance

- R^2 = .011
- p-value = .224

Appendix D Thermal Stress-Related Deaths

D.1 Overview

The risks of thermal stress, including heat and cold-related mortality, are very real and substantial. A review of heat stress trends found that the historical annual average of heat-related fatalities across the U.S., from 1975 to 2010, was 1,300.[62,63] The National Health Statistics Report offers more conservative statistics from 2006 to 2010; this report found only 620 heat-related deaths per year in the U.S., but almost twice the number of cold-related fatalities.[64] The same report noted that there were 307 thermal stress related deaths per year in the northeast region during this period.

In the year 2016, the world felt the hottest temperatures on record. Data reported by the Natural Resources Defense Council captures the impact of these extreme temperatures. In the Boston metro area alone, there were close to 70 heat-related deaths.[65] Since Boston accounts for roughly 70% of the population of Massachusetts, one could extrapolate an estimated 100 heat-related deaths statewide in 2016.

Since 2016, the U.S. keeps seeing record-breaking summer temperatures.[66] A 2020 report in *GeoHealth* claimed between 40-50 heat-related deaths per million people annually in Massachusetts, which translates to approximately 300 deaths total based on the state's population.[67,68]

The *Environmental Research Letters* reported on another study in 2020 that modeled the reduction of heat-related mortality rates through installation of green or cool roofs across all housing types throughout New England. Results indicated that heat-related mortality rates would decrease by 0.21% and 0.17% through installation of green and cool roofs, respectively. This study provides data points related to heat stress deaths and energy-efficiency measures that directly impact indoor temperatures; however, the methodology and sample population does not

62 https://www.nrdc.org/sites/default/files/killer-summer-heat-paris-agreement-compliance-ib.pdf
63 Marcus C. Sarofim et al., Temperature-related Death and Illness, chapter 2 in The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (U.S. Global Change Research Program, 2016). s3.amazonaws.com/climatehealth2016/low/ClimateHealth2016_02_Temperature_small.pdf.
64 Berko, Jeffrey, Deborah D. Ingram, Shubhayu Saha, and Jennifer D. Parker. "Deaths Attributed to Heat, Cold, and Other Weather Events in the United States," 2006–2010. National Health Statistics Reports. Number 76 (July 30, 2014). http://www.cdc.gov/nchs/data/nhsr/nhsr076.pdf
65 Constible, J. "Killer Summer Heat: Paris Agreement Compliance Could Avert Hundreds of Thousands of Needless Deaths in America's Cities." Natural Resources Defense Council. Retrieved from: https://www.nrdc.org/sites/default/files/killer-summer-heat-paris-agreement-compliance-ib.pdf
66 National Aeronautics and Space Administration, NASA, NOAA Data Show 2016 Warmest Year on Record Globally (January 18, 2017), www.nasa.gov/press-release/nasa-noaadata-show-2016-warmest-year-on-record-globally.
67 n.a. (2020). Metropolitan and Micropolitan Statistical Areas Population Totals and Components of Change: 2010-2019. U.S. Census Bureau. Retrieved from: https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-metro-and-micro-statistical-areas.html#par_textimage_1139876276
68 Massachusetts. United States Census Bureau. Retrieved from: https://data.census.gov/cedsci/profile?q=Massachusetts&g=0400000US25

allow for direct comparison with the LIMF NEI study. We did not find estimates for deaths from avoided thermal stress deaths due to the installation of standard weatherization measures in affordable MF buildings in the literature.

A study in *Environmental Health Perspectives* analyzed mortality risks from heat waves. Results indicated that with a one degree increase in heatwave intensity the risk of death is increased by close to 2.5%, and a one day increase in heat wave duration increased the risk of mortality due to heat by 0.38%.[69]

By the mid-2040s, the annual average of U.S. heat-related fatalities is predicted to climb to close to 14,000 from the historical annual average of about 1,300 from 1975 to 2010 – equivalent to about 150 deaths per summer day."[70] Boston, Baltimore, Chicago, Philadelphia, and New York are expected to experience the largest increases in heat-related fatalities.[71] The U.S. Global Change Research Program stated, "A warmer future is projected to lead to increases in future mortality on the order of thousands to tens of thousands of additional premature deaths per year across the United States before the end of this century."[72] It should be noted that cold-related illnesses and deaths are expected to decline as the world warms.

D.2 LIMF POPULATION

Social and environmental factors drive extreme temperature-related at-home mortalities.[73] A recent study (2020) looking at the association between extreme heat and at-home mortalities, specifically within the City of Boston census tracts, showed "a greater proportion of low-to-no income individuals or those with limited English proficiency being more highly represented among those who died during the study period; but small-area built environment features, like street trees and enhanced energy efficiency, were able to reduce the relative odds of death within and outside the home."[74] Individuals that have a high relative risk of dying at home when exposed to extreme heat are as follows: [75,76]

- MF housing residents;
- those that live in "intra-urban" heat islands;

[69] G. Brooke Anderson and Michelle L. Bell, "Heat Waves in the United States: Mortality Risk During Heat Waves and Effect Modification by Heat Wave Characteristics in 43 U.S. Communities," Environmental Health Perspectives 119 (February 2011), 210-218, https://doi.org/10.1289/ehp.1002313
[70] Constible, J. "Killer Summer Heat: Paris Agreement Compliance Could Avert Hundreds of Thousands of Needless Deaths in America's Cities." Natural Resources Defense Council. Retrieved from: https://www.nrdc.org/sites/default/files/killer-summer-heat-paris-agreement-compliance-ib.pdf
[71] Ibid.
[72] Marcus C. Sarofim et al., Temperature-related Death and Illness, chapter 2 in The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (U.S. Global Change Research Program, 2016). s3.amazonaws.com/climatehealth2016/low/ClimateHealth2016_02_Temperature_small.pdf.
[73] Medina-Ramón, M.; Zanobetti, A.; Cavanagh, D.P.; Schwartz, J. "Extreme Temperatures and Mortality: Assessing Effect Modification by Personal Characteristics and Specific Cause of Death in a Multi-City Case-Only Analysis." Environ. Health Perspectives. 2006, 114, 1331–1336.
[74] Williams, A.A.; Allen, J.G.; Catalano, P.J.; Spengler, J.D. "The Role of Individual and Small-Area Social and Environmental Factors on Heat Vulnerability to Mortality Within and Outside of the Home in Boston, MA." Climate 2020, 8, 29.
[75] Ibid.
[76] Heat islands are areas disproportionally dominated by heat-absorbing buildings and pavements, with minimal trees and greenery.

- those with low-socio-economic status;
- non-Hispanic persons of color;
- women;
- seniors over 65;
- children under five; and/or
- those with pre-existing medical conditions.

The entirety of the LIMF study sample can be characterized by at least two of these heat vulnerability risk factors: LI and residents of MF buildings. Furthermore, the majority of the study sample comprises seniors and female. Despite being high risk, the respondents reported hospitalizations and emergency department visits from both cold- and heat-related thermal stress relatively infrequently. A slight increase in emergency department visits from heat-related thermal stress was observed.

The team used the primary data collected by the resident survey on the number of emergency department visits (pre/post) and the secondary data from HCUP on the national rate of deaths following emergency department visits for exposure to cold-related thermal stress to calculate the rate of reduction in thermal stress-related deaths post-weatherization. The rate of avoided death for extreme cold exposure is 0.4859%. (See Section 3.3.2 for details on the monetization of the Thermal Stress (Cold) NEI.)

A production rate of 2,233 MF units weatherized per year was extrapolated using primary data provided by participating Massachusetts utilities on eligible Comparison-with-Treatment properties treated from 2008-2017. Using the Massachusetts production rate and the rate of avoided death from cold-related thermal stress, the team estimated that Massachusetts' participating LIMF weatherization programs prevent 0.16 deaths from cold-related thermal stress annually. [77] A substantial number of thermal stress-related deaths distributed across the Massachusetts general population were reported in the studies referenced above. Statistics show that a large percentage of these deaths would undoubtably occur among residents of LI housing. It is within reason to assert that reducing frequent exposure to unsafe temperatures through weatherization would avoid at least one death out of thousands of high-risk individuals. Therefore, it is certainly within reason to argue that the Massachusetts LIMF weatherization programs contribute to the avoidance of at least an average of 0.0001 deaths per year (or 14.8 deaths per 100,000 housing units weatherized per year) from cold-related thermal stress as estimated through this study (Table 16).

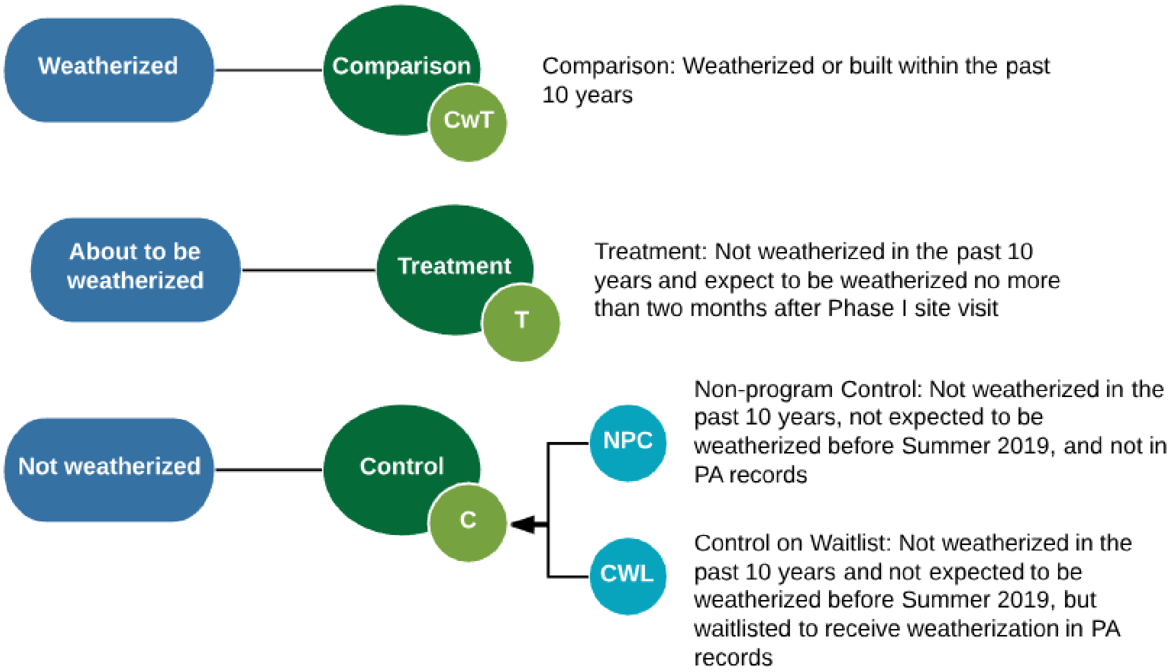
[77] 0.16 deaths prevented annually, per household = [0.4859% * 2,233 * 1.52 (mean # of persons in the home)].

Appendix E Additional Methodological Details

E.1 Study Groups

The team stratified the sample into three groups: Comparison-with-Treatment, Treatment, and Control. The Control group is composed of two subgroups: the Non-Program Control and Control on Waiting List. We define the groups and subgroups in Figure 10.

Figure 10: Study Groups



E.2 Classifying Projects' Weatherization Status

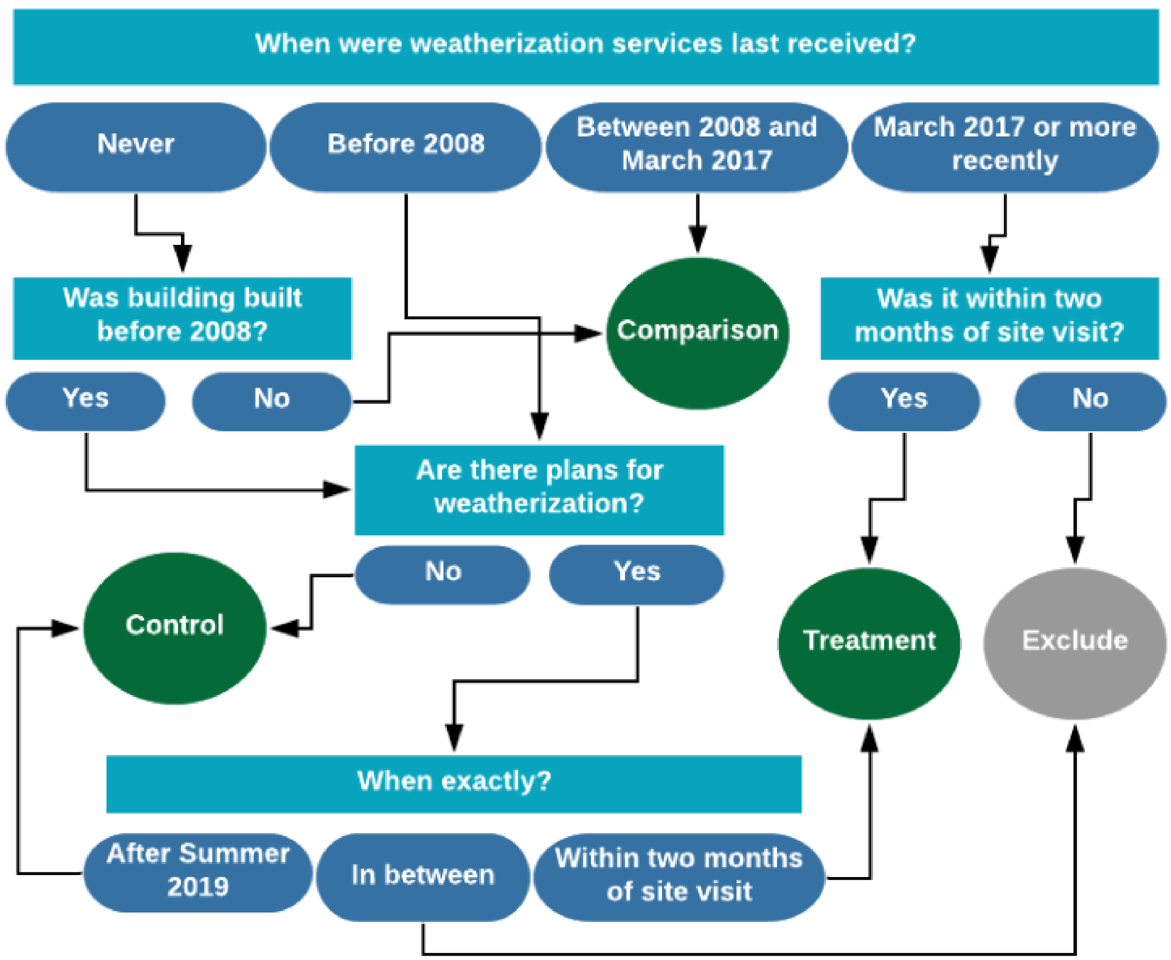
We used program participation data fields, such as Application Status and Project Status, to preliminarily classify Massachusetts project sites into study groups, using the following order of operations:

1. **Comparison (CwT) (surveyed in Phase 1 only)**. If a project's Application Status was designated in the database as *paid*, *invoiced*, or *installation complete,* or if the Project Status was *completed* prior to March 2017, we classified them as CwT.
2. **Treatment (T)**. We classified projects with an Application Status of *audit complete* or Project Status of *audited/work pending*, *installation contractor selected*, or *contract signed* as Treatment projects.

3. **Control on Waitlist**. If a project did not have an install date and had an Application Status of *pre-audit* or a Project Status of *not yet audited,* we placed them in the Control on Waiting List group.
4. **Excluded**. If sites were unlikely to be MF based on the ratio of number of housing units to buildings (i.e., an average of less than five units per building), weatherized after March 2017, listed as *canceled,* or for any other reason appeared to be currently in the process of receiving weatherization services, we excluded them from the sample.

Recruiters verified each site's status by asking when weatherization services were last received, when the building was built, and about any near-term plans for receiving weatherization services. We considered a site to be weatherized if it had been insulated, been air- or duct-sealed, or had energy-efficient heating or cooling equipment installed within the past ten years. We also considered sites built in the last ten years as weatherized. Figure 11 maps the classification process. To qualify as a Treatment project in Phases 1 and 2, a site had to have been weatherized within two months before and two months after the Phase 1 site visit.

Figure 11: Weatherization Classification Process



E.3 Developing a Non-Program Control Group

As noted earlier, we used multiple non-PA data sources to develop the Non-Program Control group. For Massachusetts sampling, this involved contacting roughly 50 housing authorities; reviewing publicly listed properties through community and economic development corporations; and cataloguing over 250 LI properties using the Boston Metrolist, a clearinghouse of income-restricted and affordable housing opportunities in Boston and neighboring communities, posted by the city of Boston.[78] The broader JPB study undertook similar types of research to develop their sample frame for other states.

We also collaborated with the *RES38 Income-Eligible Process Evaluation* team, who prepared a database of income-eligible properties in Massachusetts using property tax data. Additionally, as in other JPB states, our Massachusetts recruiters asked *all* PMs (not just Control group PMs) if they managed or owned other sites that they did not expect would receive weatherization in the coming two years.

Our Control sample frame did not encompass all possible Control sites due to the following reasons:

1. Not all housing authorities and property management agencies of Non-Program Control properties were willing to speak with us about their properties. Site characteristics were not always included in the publicly available lists. (Section 2.1 discusses recruitment rates.)
2. Not all sites provided by the Massachusetts PAs and CAP met study eligibility criteria. Of the 535 Massachusetts sites we contacted, 83 (16%) were ineligible.[79]
3. The RES38 property tax data did not include the site details needed to determine if sites met study eligibility criteria. In an attempt to mirror population characteristics, we prioritized RES38 sites based on their size and metro area and contacted 80 of them.[80] Twelve (15%) were ineligible.

E.4 Phase 1 Sample Frame

Table 81 summarizes the sample frames for Massachusetts and the states in the JPB study. In addition to weatherization status, the original sampling plan considered rise, number of units, ownership structure, and metropolitan-statistical area (MSA).[81,82] Sites in the sample frame were most often low-rise (less than five floors), in buildings with fewer than 80 units, and in urban areas. Our recruitment approach initially attempted to mirror the distribution of these characteristics.

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[78] https://www.boston.gov/metrolist
[79] On average, for Phase 1, each Control site was contacted over three times, Treatment site over six times, and Comparison-with-Treatment sites about three times.
[80] The RES38 data included over 1,700 properties.
[81] The National Center for Health Statistics (NCHS) developed a six-level urban-rural classification scheme for U.S. counties. We considered the two most urban levels (large central metro and large fringe metro) to be one metro area, and the four most rural levels (medium metro, small metro, micropolitan, and non-core) to be a second metro area. This site describes the MSA categories and provides the classifications by county: https://www.cdc.gov/nchs/data_access/urban_rural.htm
[82] We considered developing targets by housing function (e.g., senior, family), but PA data did not widely capture this characteristic.

Table 81: Sample Frame Property Site Characteristics[1]

Property Characteristic	Comparison-with-Treatment				Treatment				Control[3]			
	MA		Other States[2]		MA		Other States		MA		Other States	
	Sites	Units	Sites	Units	Sites	Units	Sites	Units	Sites	Units	Sites	Units
n	**474**	**33,580**	**239**	**14,605**	**55**	**4,288**	**126**	**6,715**	**458**	**4,216**	**63**	**3,804**
Rise												
Low-rise (< 5 stories)	82%	61%	71%	38%	76%	51%	58%	47%	11%	48%	75%	54%
Mid-rise (5 to 9 stories)	11%	19%	10%	16%	13%	28%	10%	9%	2%	14%	13%	26%
High-rise (10+ stories)	5%	14%	12%	44%	6%	20%	5%	18%	1%	15%	6%	19%
Unknown	3%	6%	7%	3%	6%	1%	26%	25%	86%	22%	6%	2%
Size (housing units)												
5 to 10 units	17%	2%	47%	14%	18%	1%	33%	4%	3%	2%	30%	4%
11 to 79 units	50%	27%	29%	25%	42%	23%	48%	26%	9%	33%	41%	24%
80 to 149 units	17%	26%	19%	40%	20%	26%	10%	19%	2%	26%	14%	25%
150 + units	12%	45%	5%	21%	15%	50%	10%	50%	2%	39%	14%	47%
Unknown	3%	†	0%	0%	5%	†	1%	†	84%	†	0%	0%
Metro-Statistical Area												
Large central and fringe metro	75%	71%	26%	312%	69%	74%	62%	57%	91%	68%	51%	58%
Medium and small metro, micropolitan	25%	29%	74%	88%	31%	26%	38%	43%	7%	32%	49%	42%

[1] Percentages may not total 100% due to rounding and because property site characteristics were not always available.
[2] Other states include Illinois, Michigan, Wisconsin, New York, Rhode Island, New Hampshire, and Vermont.
[3] Only includes sites for which we could verify or clearly observe eligibility.
† Data not available.

E.5 Phase 2 Sample Frame

Before beginning Phase 2 surveys, the team verified that all Treatment buildings had received weatherization and that all Control buildings had *not* received weatherization since the Phase 1 survey. If weatherization had not been completed as scheduled on a Treatment building, it was shifted to the Control group. If a building that categorized as Control received weatherization within 1-2 months after Phase 1, it was shifted to the Treatment group.

Table 82 shows sample sizes by Treatment and Control group by state. Respondents from Illinois dominated the Control group, while New York, Rhode Island, and Massachusetts respondents represented the majority of the Treatment group. As mentioned previously, the team had to rely on a convenience sampling approach, which resulted in an unintended imbalance among states. Some of our partnering weatherization agencies were simply not weatherizing MF buildings at the anticipated rate, such as in Illinois and Massachusetts, but were able to contribute many Control buildings.

Table 82: Phase 2 Sample Frame for Treatment and Control Groups by State

	T (HHs)	T (Sites)	C (HHs)	C (Sites)	TOTAL (HHs)
IL	2	1	534	20	544
MA	82	10	173	23	254
NY	133	16	28	3	161
RI	130	3	67	3	198
VT	12	2	3	1	15
WI	32	15	46	10	64
NH	22	2	0	0	22
PA	4	1	41	4	46
Total	**417**	**50**	**892**	**64**	**1,309**

E.6 Air-Source Heat Pumps

The PAs asked the team to prioritize projects where ASHPs were installed with program support.[83] Given the potential for additional health and safety impacts for ASHPs – including those associated with cooling – and PA concerns about the cost-effectiveness of ASHPs, assessing health and safety characteristics of these projects offers opportunities for NEIs to be factored into the measure's cost-benefit ratio. The sample frame included 24 sites where program data indicated ASHPs had been installed through the program: one Control on Waiting List, three Treatment, and 20 Comparison with Treatment. The team attempted to contact and recruit all sites with ASHPs and looked for ASHPs while in the field to identify sites not captured in the original program data. Ultimately, we were only able to recruit five sites with ASHPs.

[83] This was ultimately only relevant for Comparison-with-Treatment sites since we had to conduct census sampling for Treatment and Control on Waiting List sites.

Appendix F Existing Systems and Installed Measures

The team analyzed data provided by participating agencies on existing (i.e., pre-weatherization) mechanical systems and weatherization measures installed through the PAs' programs and through programs in the other states. Table 83 shows the prevalence of pre-weatherization ventilation and heating/cooling systems, respectively, in a subsample of the Comparison-with-Treatment and Treatment buildings. Prior to weatherization, 19% of units did not have a working mechanical ventilation system. Of those that did have ventilation, more than half (65%) had bathroom fans, while only 22% had a kitchen range hood that vented to the outside.

Table 83: Existing Ventilation Measures – Pre-Weatherization

Subsample of CwT and T Buildings (n=189 buildings)	% of Units[1] (n=3,484)
Existing Ventilation System[2]	
No Working Mechanical Ventilation System	**19%**
In-unit bathroom fan	65%
Kitchen Range Hood (that vents outside)	22%
In-unit central exhaust	12%
Building has corridor supply	12%
Building has "Other"	1%
Building has corridor exhaust	3%
In-unit central supply	0%

[1] Some totals do not equal 100% as not all answers were mutually exclusive.
[2] Of those that reported having some type of ventilation system present pre-weatherization.

The most common heating system prior to weatherization was central hot water/steam boiler (65%), followed by individual electric baseboard (18%). Two percent of the units reported individual split system heat pumps or in-unit air-source heat pumps (ASHPs). While 3% of units did not have a working heating system, 30% did not have a cooling system. This difference is reflective of the northern, colder climates in which most buildings were located. Of those units with a cooling system, 20% had window or wall A/C, 18% reported a central chiller, and 16% had in-unit sleeve A/C.

Table 84: Existing Heating/Cooling Measures – Pre-Weatherization

Subsample of CwT and T Buildings (n=189 buildings)	% of Units[1] (n=3,484)
Existing Heating System (Pre-Weatherization)[2]	
No Working Heating System	**3%**
Building has central hot water/steam boiler	65%
Individual electric baseboard	18%
Building has "Other" heating system (no description provided)	8%
Individual forced air furnace	5%
Individual split system heat pump	2%
Individual ASHP	0%
Existing Cooling System (Pre-Weatherization)[2]	
No Working Cooling System	**30%**
Individual window/wall unit	20%
Building has central chiller	18%
Individual sleeve A/C	16%
Building has "Other" cooling system (no description provided)	1%
Individual packaged terminal air conditioner	1%
Individual split-system or heat pump	2%

[1] Some totals do not equal 100% as not all answers were mutually exclusive.
[2] Of those that reported an existing working heating system or cooling system pre-treatment.

Table 85 energy-saving measures that were installed in the Comparison-with-Treatment and Treatment subsample. In-unit, hallway/stairwell, and building exterior lighting improvements (e.g., new bulbs and/or fixtures) were the most common set of measures reported, at 84%, 61%, and 61%, respectively. The second most common measure installed in the Comparison-with-Treatment and Treatment subsample was building-level air sealing (55%), followed by heating equipment (52%), new refrigerators (52%), insulation[84] (50%), water-saving devices (47%), domestic hot water (37%), and mechanical ventilation (27%). Cooling equipment and windows were the least common measures, at 18% and 14% of buildings, respectively.

[84] Includes the following insulation types: above-grade wall, floor, rim/band joist, and foundation wall insulation.

Table 85: Installed Energy Conservation Measures – Post-Weatherization

Energy Conservation Measures	% of buildings (n=189)
Lighting (within unit)	84%
Lighting (hallway/stairwell)	61%
Lighting (exterior of building)	61%
Air Sealing	55%
Heating Equipment (replacement or repair[1])	52% [2]
New Refrigerator	52%
Insulation (any type)	50%
Water Saving Device	47%
Domestic Hot Water	37%
Mechanical Ventilation	27% [3]
Cooling Equipment	18% [4]
Windows	14%

[1] Sixteen percent (of the 52%) included repairs, programmable thermostats, or pipe insulation.
[2] Thirteen percent of changes made to heating systems were justified by health and safety.
[3] Twenty-one percent of changes made to ventilation systems were justified by health and safety.
[4] Six percent of changes made to cooling systems were justified by health and safety.

Table 86 reports measures installed specifically due to health and safety concerns. Structural repairs, reported as “Other” health and safety measures, were the most common (20%). Common areas in 5% of buildings received asbestos and lead paint remediation and smoke detectors. Seven percent of buildings received in-unit smoke detectors and 5% received some in-unit electrical repairs. The low rate of CO monitor installation (5%) impeded the team’s ability to monetize avoided CO poisoning.

Table 86: Installed Health & Safety Measures – Post-Weatherization

Health & Safety Measures Installed	% of buildings (n=189)
“Other” Health and Safety Measures	20%[1]
Emergency Lighting	9%
Electrical Repairs (in common area)	7%
Smoke Detectors (in unit)	7%
Smoke Detectors (in common area)	5%
CO Monitors (in unit)	5%
Electrical Repairs (in unit)	5%
Asbestos Remediation (in common area)	5%
Lead Paint Remediation (in common area)	5%

[1] Forty-three percent (of the 20%) included structural or general repairs.

G

Appendix G Summary Statistics

The tables in this appendix report Treatment and Control respondents' perceptions of their dwellings' safety and quality, respectively. The results in the far-right column of these tables are based on the classic DID calculation. This captures changes experienced by Control group respondents, ensuring that the changes reported by the Treatment respondents can be attributed to weatherization rather than external factors. In this section, we see a number of reductions in various conditions, but none is statistically insignificant.

G.1 Dwelling Quality, Safety, and Other Conditions

Despite the fact that lighting upgrades were the most common measures installed in the Treatment subsample that returned an IM-DCF, the Treatment group as a whole reported no change in how dark their building hallways and stairwells were. It is possible the lighting upgrades included lightbulb replacement but not additional lighting fixtures. The survey also did not ask about brightness or darkness inside units, only in hallways and stairwells and outside the building. There were no statistically significant changes in the frequency of building or unit fires. This was expected given that fires rarely occur. Larger sample sizes would be needed to properly measure fire incidence.

Table 87: Changes in Dwelling Safety

Resident Survey Question (Respondent Only)	Treatment		Diff.	Control		DID[1]
	P1 (pre-Wx)	P2 (post-Wx)		P1	P2	
Inside of building is somewhat dark, very dark	12.0% (n=196)	12.0%	0.0%	7.1% (n=541)	6.2%	+0.9%
Outside of building is somewhat dark, very dark	14.8% (n=176)	15.4%	+0.6%	15.9% (n=532)	14.7%	+1.8%
# times fire department called - last 12 mo (mean)	0.08 (n=136)	0.01	-0.07	.02 (n=479)	0.01	-0.06
Fire as a result of using alternate heating source - last 12 mo (Yes)	1.1% (n=183)	0.5%	-0.6%	0.4% (n=543)	0.6%	-.0.8%

[1] This column presents the results of the classic DID equation to calculate changes in incidence rates among household members represented in both the pre- and post-weatherization surveys , (ITpost – ITpre) – (IC2 – IC1).

As Table 88 shows, post-weatherization, there was a 7% increase in reports of pest infestation and an incremental increase in rodent infestation. A small decrease in visible mold inside the home was reported. These are all evidence-based asthma triggers. (See Appendix A.2 for a discussion on asthma).

Table 88: Changes in Dwelling Quality

Resident Survey Question (Respondent Only)	Treatment		Diff.	Control		DID
	P1 (pre-Wx)	P2 (post-Wx)		P1	P2	
Home is extremely or very infested with pests (Yes)	71.2% (n=170)	77.6%	+6.5%	84.6% (n=518)	83.8%	+7.2%
Home is extremely or very infested with rodents (Yes)	67.6% (n=165)	70.0%	+2.3%	86.3% (n=525)	87.8%	+0.8%
Visible mold - past 12 months (Yes)	30.7% (n=163)	28.8%	-1.8%	14.7% (n=482)	13.5%	-0.6%

G.2 General Health

As shown in Table 89, the Treatment group reported a slight increase (about 1.5) in the mean number of days that their mental or physical health was "not good" or that "poor" physical or mental health impacted usual activities.

Table 89: Changes in General Health

Resident Survey Question (Respondent Only)	Treatment		Diff.	Control		DID
	P1 (pre-Wx)	P2 (post-Wx)		P1	P2	
# days mental health "not good" - past 30 days (mean)	7.1 (n=183)	7.3	+0.2	5.8 (n=480)	4.6	+1.4
# days "poor" physical or mental health impacted usual activities - past 30 days (mean)	5.4 (n=180)	6.3	+0.9	4.4 (n=468)	3.7	+1.6

G.3 HOUSEHOLD BUDGET AND AFFORDABILITY ISSUES

Table 90 presents results from questions about challenges respondents faced in affording their energy bills and trade-offs they made in order to pay for energy. Sample sizes in the Treatment group were low, in part because only 36% (n=195) directly paid for an energy bill in Phase 2; the other 64% had all utilities included in their rent. While the percent of households receiving energy assistance went down by 8.4% from Phase 1 to Phase 2, the difference was not statistically significant. On the whole, these findings indicate that LIMF weatherization has minimal impact on household energy burden and budgetary trade-offs.

Table 90: Energy Affordability and Trade-Offs

Resident Survey Question (Respondent Only)	Treatment		Diff.	Control		DID
	P1 (pre-Wx)	P2 (post-Wx)		P1	P2	
Received a disconnect, shut-off, or non-delivery notice almost every month, or some months, over past 12 months (Yes)	16.7% (n=42)	21.4%	+4.8%	8.7% (n=229)	11.4%	+2.1%
Electricity or natural gas disconnected because could not afford (Yes)	6.1% (n=49)	6.1%	0.0%	3.6% (n=249)	5.2%	-1.6%
Very hard or hard to pay energy bills (Yes)	37.5% (n=40)	40.0%	+2.5%	37.0% (n=238)	34.5%	+5.0%
Did not fill a prescription in order to pay an energy bill every or every other month - past 12 months (Yes)	4.7% (n=43)	4.7%	0.0%	2.9% (n=239)	0.8%	+2.1%
Did not pay an energy bill in order to fill a prescription every or every other month - past 12 months (Yes)	2.6% (n=36)	5.3%	+2.6%	1.3% (n=225)	0.0%	+4.0%
Received energy assistance this past year	31.3% (n=42)	22.9%	-8.4%	47.9% (n=229)	47.9%	-8.4%

Appendix H Attribution by Measure

For the purposes of our attribution by measure analysis, we computed a composite variable that aggregates the household monetized values attributable to a subset of individual NEIs for $Household_a$ at $Time_y$.[85]

The individual NEI variables we selected for inclusion in the composite variable were those that (1) only produced household benefits or produced both household and societal benefits, (2) were *not* derived from bill savings, and (3) exhibited survey results that indicated that weatherization yielded an NEI. The subset of NEIs included in the composite NEI variable that was used in the attribution by measure approach is as follows:

- Thermal Stress (Cold)
- Arthritis
- Trips and Falls
- Home Productivity
- Missed Days of Work

NEIs based on the value of avoided medical costs (Arthritis, Thermal Stress, Trips and Falls) follow these general steps:

1. *The number of times seeking medical treatment at care setting X for treatment of condition A is multiplied by the cost of treatment for condition A to produce value X_y. Repeat for each care setting of condition A and add all care settings together into X_A.*
2. *The number of times seeking medical treatment at care setting X for treatment of condition B is multiplied by the cost of treatment for condition B to produce value X_z. Repeat for each care setting of condition B and add all care settings together into X_B.*

For example, if household #1 reported two doctor's office visits for thermal stress, then one component of the calculation would be 2 * the cost to the household for treatment of condition A (e.g., thermal stress) for care setting X (e.g., doctor's office). If no one in the household reported being treated for thermal stress in any care setting, then the value for this component would be zero. The same logic is used for arthritis. If no one in household #1 reported having arthritis (e.g., condition B), then the value for this component would be set to zero. Otherwise, the composite value for arthritis would be based on the number of reported medical encounters multiplied by the cost of these encounters.

1. *Continue steps for remaining NEIs (X_I and so on...)*

For NEIs unrelated to medical encounters – Home Productivity and Missed Days of Work – the team adapted their individual monetization methodologies (see Appendix A) for the composite approach. For Home Productivity, this meant estimating the productivity losses attributable to one night's poor sleep and multiplying it by the number of days of poor sleep reported by the

[85] $Time_y$ is either Phase 1 or Phase 2.

respondent. For Missed Days of Work, the team multiplied together (1) the number of days missed by the primary wage earner, (2) the average wage for a LI worker in MA, and (3) eight hours of work in a day.

2. *Sum of* $X_A + X_B + X_C$... = *Composite NEI Value*

Figure 12 provides the parameters and results from the regression model that includes the change in composite NEI value as the dependent variable. The team used estimates of change from the regression to determine how to allocate the recommended NEI values to the relevant measures in the PAs' BCR models.

Figure 12: Attribution by Measure – Regression Analysis Parameters and Results

Key coefficient / estimate of Δ

- Beta coefficient from regression estimate (Air Sealing + Insulation) = -288.96
- Beta coefficient from regression estimate (Heating system) = -312.37

Dependent variable:

- Difference between Phase 1 and Phase 2 total household NEI value including VSL (composite variable)

Independent variables:

- Combined measures (air sealing and insulation)
- Heating system changes (repair/replacement)

Dataset characteristics:

- Regression performed on Phase 1 and Phase 2 household-level data – Treatment group only.
- Composite variable for *combined* measures was created for air sealing and insulation (See Section 3.4 in the report)

Significance:

- R^2 = .098
- Air Sealing + Insulation; p = .056
- Heating System, p = .029

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	658.151	133.734		4.921	.000
	AirSealingANDInsulation	-288.960	148.974	-.198	-1.940	.056
	12_HeatingSystemChanges	-312.367	141.012	-.226	-2.215	.029

a. Dependent Variable: Diff_T1andT2Total$houVSL

Equation 1: % attribution for [Air Sealing + Insulation] (X) = % of measure combination X / (sum of % of measure combination X + Y)

- -288.96 / (-288.96 + -312.367) = **48%** attribution for [Air Sealing + Insulation]

Evenly split **48%** attribution for [Air Sealing + Insulation] = **24% for air sealing and 24% for insulation**

Equation 2: % attribution for Heating System (Y) = % of measure Y / (sum of % of measure combination X + Y)

- -312.367/(-288.96 + -312.367) = **52% attribution for heating system changes**

Appendix I Unrounded Estimated NEI Values

Table 91 presents the individual monetized values to the nearest cent for the four LIMF NEIs recommended for adoption by the PAs. We calculated each NEI estimate using the individualized monetization algorithms and inputs presented in Section 3.3.

Table 92 shows the estimated NEI values for the NEIs not recommended for adoption due to lack of statistical precision. We calculated each NEI estimate using the individualized monetization algorithms and inputs presented in Appendix A.2.

All NEI estimates are presented on a per-weatherized-unit basis, broken out by their societal and household benefit components. We present NEIs that include the benefit of avoided deaths both with and without the VSL.

Table 91: Estimated Annual Values (Unrounded) of Recommended NEIs Per Weatherized Housing Unit

(With and Without VSL)

Annual NEI Values	Per HH w/ VSL[1]	Per HH w/o VSL	Societal	Total	Total w/o VSL
Arthritis	$**49.07**	$49.07	$892.06	$941.13	$941.13
Thermal Stress (Cold)	$**1,425.90***	$7.80	$38.03	$1,463.93	$45.83
Home Productivity	**$48.90**	$48.90	$0.00	$48.90	$48.90
Reduced Fire Risk	**$12.96**	$2.07	$4.12**	$17.08*	$6.04***
Annual Total for Recommended NEIs per Weatherized Housing Unit	**$1,536.83**	**$107.84**	**$934.21**	**$2,471.04**	**$1,041.90**

[1] HH = household (assuming one household per housing unit)
* The total Thermal Stress (Cold) NEI of $1,426 includes doctor's office visits ($1.41) + emergency dept. visits that do not result in deaths ($6.39) + the value of avoided death: $1,418.10.
** The value of societal benefits without including firefighter deaths (VSL) is $3.97; with firefighter deaths (VSL) the societal benefit is $4.12.
*** Total w/o VSL for Home Fires does not include the $0.15 societal benefit per unit for firefighter deaths (VSL); therefore, the total sum of HH w/o VSL plus societal benefits is $6.04 rather than $6.19.

Table 92: Estimated Annual Values (Unrounded) of NEIs Not Recommended, Per Weatherized Housing Unit

(With and Without VSL)

Estimated Annual NEI Values	Per HH w/ VSL[1]	Per HH w/o VSL	Societal	Total	Total w/o VSL
Food Spoilage	$57.20	$57.20	$0.00	$57.20	$57.20
Trips and Falls	$3.26	$3.26	$46.36	$49.62	$49.62
Missed Days of Work	$8.41	$8.41	$2.51	$10.92	$10.92
Short-Term, High-Interest Loans	$2.32	$2.32	$0.00	$2.32	$2.32
Work Productivity	$0.00	$0.00	$16.91	$16.91	$16.91
Prescription Adherence	$0.00	$0.00	$58.78	$58.78	$58.78
Food Assistance	$0.00	$0.00	$98.76	$98.76	$98.76
Low-Birth-Weight Babies	$0.47	$0.47	$10.09	$10.56	$10.56
Asthma	$0.00	$0.00	$0.00	$0.00	$0.00
Thermal Stress (Heat)	$0.00	$0.00	$0.00	$0.00	$0.00
Annual Total NEI per Weatherized Housing unit	**$71.66**	**$71.66**	**$233.41**	**$305.07**	**$305.07**

[1] HH = household (assuming one household per housing unit)

Appendix J References

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