# Massachusetts Special and Cross-Cutting Research Area: Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts (NEIs) Study

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# Executive Summary

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

In 2011, the NMR Group[1] conducted an evaluation study of non-energy impacts (NEIs) attributable to the Massachusetts (MA) Program Administrators' (PAs') residential and low-income (LI) programs that examined a number of health and safety-related benefits to LI residents.[2] In 2015, an evaluation of the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) was completed that included the assessment and monetization of twelve health and household-related impacts attributable to the weatherization of income-eligible single-family (SF) homes, at a national level.[3,4] Three[3] (pronounced Threecubed) research staff, under the auspices of Oak Ridge National Laboratory, conducted this DOE funded evaluation. In order to complement NMR's findings, the MA PAs contracted Three[3] to assess and monetize a sub-set of these NEIs experienced by recipients of energy efficiency services residing in income-eligible households in the state of MA. The subset of eight NEIs was selected based on their estimable, direct impact on the household, which was of most interest to the PAs; whereas, the remaining four estimated only societal impacts (i.e., reduced need for food assistance, improvement in prescription adherence, increased productivity at work due to improved sleep, reduction in low-birth weight babies from heat or eat dilemma). The subset of NEIs selected for Three[3]'s MA LI SF NEI study are as follows:

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

The national WAP NEI evaluation research was utilized as the foundation for the MA LI SF NEI study; although, in order to conduct a state-level analysis, inputs needed to be context sensitive.

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[1] http://www.nmrgroupinc.com/

[2] NMR. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for Massachusetts Program Administrators. (See: http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf)

[3] A complete report presenting findings from this component of the WAP evaluation was published in 2014 and can be found at www.threecubed.org.

[4] A complete description of the methodology is found in: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.

Slight modifications were made to the research method and several inputs were revised based on updated or context specific data (modifications are discussed in more detail in Section 2.3). Each NEI required a customized approach; however, several adopted a similar framework and, when appropriate, utilized uniform inputs.

The PAs tasked NMR to review the methodology utilized for the national WAP evaluation, as well as the findings from the MA LI SF NEI study presented in this report. The purpose of this task was to determine the extent to which the NEIs quantified in this WAP-based evaluation overlap with, augment, or supersede the health- and safety-related NEIs previously examined and/or currently claimed by the PAs, and to develop recommendations for integrating the results.

Underpinning the methodology utilized to estimate the NEIs attributable to the national WAP was a pre-tested, national Occupant Survey of a random and representative sample of weatherized single-family[5] homes pre- and post-weatherization, along with a comparison group of homes. The Occupant Survey was administered in two phases.[6] In phase 1, the survey was administered just prior to the energy audits completed in the treatment group households. The second phase was implemented post-weatherization, approximately 18 months later. In addition, a group of homes that had already been weatherized one year before the treatment group received weatherization services was surveyed during phase 1; this group of homes served as a post-weatherization comparison group.

During the data analysis design phase, the issue of whether sample sizes were large enough to capture rare events was encountered. For example, the Occupant Survey asked questions about the incidence of fires and CO poisoning pre- and post-weatherization. The responses indicated that both were very rare given the sample size, and national data supports these conclusions. However, preventing fires and CO poisoning are policy relevant and important NEIs of weatherization; therefore, we believe that estimating the monetized benefits of reducing fires and CO poisoning are worthwhile given that deaths could be prevented. So, in these two instances, data collected through the national evaluation on weatherization measures installed (e.g., various measures that map specifically to fire ignition risks or serve as fire suppressors), national Occupant Survey responses for CO monitors installed that may reduce the incidence of CO poisoning, along with secondary data were relied upon to anchor the methodologies.

Descriptive statistics generated from these surveys demonstrated post-weatherization benefits. For several of the NEIs, the differences between the treatment groups pre- and post-weatherization were statistically significant. Many differences between the pre-weatherization treatment group and the post-weatherization comparison group were also statistically significant.

Additionally, these findings were augmented by anecdotal evidence offered by the human stories shared by the weatherization agencies and by recipients of the programs themselves. Ultimately, these benefits were analyzed from multiple angles. Triangulation as a research method (i.e., arriving at conclusions by using multiple sources of information) is common within the social sciences. Because the benefits selected for analysis were approached in this way, the Three[3] researchers were able to confidently monetize changes in occurrences even if they did not

[5] Single-family homes surveyed included mobile homes and small multifamily buildings consisting of between two and four units.

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

achieve statistical significance for the reasons explained above. A national panel of experts reviewed all methodologies and assumptions—the panel did not question the validity of any of the NEIs nor were the findings dismissed as inconsiderable as there was a clear indication of health improvements.

For the national WAP evaluation, the estimated NEI values were presented on a dollar per weatherized unit basis, broken down by both societal and household cost benefit categories based on health care coverage:

- For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs was categorized as a societal benefit;
- For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (i.e., copayments, deductibles) were categorized as a household benefit; and
- For individuals/occupants that are "uninsured," all of the avoided medical costs was categorized as a household benefit.[7]

With respect to the cost benefit of avoided deaths, if applicable, two separate values were presented: one with the Value of Statistical Life (VSL), or the benefit of avoided deaths, included and one without.[8] Based on discussions with reviewers, it was decided that the benefit of avoided deaths, or VSL, would be considered a societal benefit. Also, the present value (PV) of all benefits were estimated over a twenty-year time horizon reflecting the persistence of the measure.[9] Lastly, as recommended by the national panel of experts, estimates were categorized and presented in three tiers. Tier 1 included estimates based on observed monetizable outcomes attributable to weatherization and highly reliable cost data. Tier 2 and 3 estimates were established to have underlying sound methodologies but may have lacked direct observations of improved health or well-being and/or required relatively more assumptions.

The presentation of estimated NEI values for the MA LI NEI study are similar to the national WAP evaluation in that values are presented on a per weatherized unit basis, broken down by their household and societal benefit components, a PV estimate of the benefits is provided, and estimates are presented in three tiers. Lastly, VSL associated with avoided deaths (except for firefighters) was applied as a household benefit rather than a societal benefit (See Section 2.3.1 for a detailed discussion on avoided death benefits and VSL).[10]

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

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

[9] With the exception of the non-energy impact of installing CO monitors, where present value was calculated over a more conservative 5-year period as the lifespan of CO monitors generally remains effective for an average of five years.

[10] The VSL of $7.5M used in the national WAP evaluation was updated to $9.6M, a 2016 VSL recommended by the U.S. Department of Transportation (DOT). In an effort to utilize a context-sensitive VSL, a thorough scan of MA government agencies' usage of VSL's for cost-benefit analyses was conducted. The DOT's Office of General Council updates this VSL annually and releases an annually revised memo entitled: *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses.*

Table E.1 presents the annual estimated values of the monetized NEIs selected for the MA LI SF NEI study, per weatherized unit—for both societal and household benefit categories. The overall valuation results are driven quite strongly by the assertion that the program is saving lives; however, given the uncertainty surrounding the estimate of the number of deaths avoided, the household cost savings have been presented both with and without the avoided death benefit.

The main contributors to estimates presented in Table E.1 are: avoided deaths from thermal stress, CO poisoning, and home fires; avoided hospitalizations and emergency department (ED) visits related to these three areas as well as asthma-related symptoms; and disposable income gains from fewer missed days at work. Table E.2 provides the PV for the estimates presented in Table E.1. Table E.3 provides a breakdown of the avoided number of deaths, if any, and hospitalizations, ED visits, and physician office visits annually for each health-related NEI, per 1,000 units weatherized.

**Table E.1. Estimated MA Low-Income Household and Societal NEIs Per Weatherized Unit both With and Without Avoided Death Benefit—Annual per Unit**

| NEI Value | Annual Per Unit Benefit* | | | | |
|---|---|---|---|---|---|
| | Household | Household W/O Avoided Death Benefit | Societal | Total | Total W/O Avoided Death Benefit |
| **Tier 1** | | | | | |
| Reduced asthma symptoms | **$9.99** | $9.99 | $322.01 | **$332.00** | $332.00 |
| Reduced cold-related thermal stress | **$463.21** | $4.67 | $33.73 | **$496.94** | $38.40 |
| Reduced heat-related thermal stress | **$145.93** | $8.28 | $27.00 | **$172.93** | $35.28 |
| Fewer missed days at work | **$149.45** | $149.45 | $37.36 | **$186.81** | $186.81 |
| **Tier 2** | | | | | |
| Reduced use of short-term, high-interest loans | **$4.72** | $4.72 | $0 | **$4.72** | $4.72 |
| Reduced CO poisoning (5-year life) | **$36.98** | $0.25 | $1.87 | **$38.85** | $2.12 |
| **Tier 3** | | | | | |
| Increased home productivity | **$37.75** | $37.75 | $0 | **$37.75** | $37.75 |
| Reduced home fires | **$93.84** | $9.77 | $17.87** | **$111.71** | $27.37** |
| **Annual Total—per weatherized home** | **$941.87** | **$224.88** | **$439.84** | **$1,381.71** | **$664.45** |

*For CO poisoning, the annual NEI is to be applied over the 5-year life of the CO monitor. The remaining NEIs are to be applied annually over the life of the relevant measure (e.g., 20 years for weatherization).
**For home fires, the avoided injuries and deaths to firefighters are categorized as a societal benefit.

**Table E.2. Estimated MA Low-Income Household and Societal NEIs Per Weatherized Unit both With and Without Avoided Death Benefit— Per Unit at Present Value (20 Years at 0.44%)**

| NEI Value | PV (20 years) Per Unit Benefit | | | | |
|---|---|---|---|---|---|
| | Household | Household W/O Avoided Death Benefit | Societal | Total | Total W/O Avoided Death Benefit |
| **Tier 1** | | | | | |
| Reduced asthma symptoms | **$190.92** | $190.92 | 6,151.96 | **$6,342.88** | $6,342.88 |
| Reduced cold-related thermal stress | **$8,849.71** | $89.30 | $644.47 | **$9,494.18** | $733.77 |
| Reduced heat-related thermal stress | **$2,787.95** | $158.19 | $515.86 | **$3,303.81** | $674.05 |
| Fewer missed days at work | **$2,855.21** | $2,855.21 | $713.80 | **$3,569.01** | $3,569.01 |
| **Tier 2** | | | | | |
| Reduced use of short-term, high-interest loans | **$90.18** | $90.18 | $0 | **$90.18** | $90.18 |
| Reduced CO poisoning (5 years)* | **$183.30** | $1.25 | $9.28 | **$192.58** | $10.53 |
| **Tier 3** | | | | | |
| Increased home productivity | **$721.26** | $721.26 | $0 | **$721.26** | $721.26 |
| Reduced home fires | **$1,792.84** | $186.68 | $341.39** | **$2,134.23** | $522.96** |
| **PV Total—per weatherized home** | **$17,471.37** | **$4,292.99** | **$8,376.76** | **$25,848.13** | **$12,664.64** |

*For CO poisoning, PV is estimated for 5 years
** For home fires, the avoided injuries and deaths to firefighters are categorized as a societal benefit.

**Table E.3. Number of Avoided Deaths, Hospitalizations, ED Visits, and Physician Office Visits Annually for Each Health-Related NEI, Per 1000 Units Weatherized**

| NEI | Deaths | Hospitalizations | ED Visits | Physician Office Visits |
|---|---|---|---|---|
| **Asthma** | - | 9.9 (adult)<br>4.2 (child) | 54.6 | - |
| **Cold-related Thermal Stress** | 0.05 | 1.9 | 7.6 | 9.5 |
| **Heat-related Thermal Stress** | 0.01 | 1.1 | 23.6 | 3.2 |
| **CO Poisoning** | 0.004 | 0.07 | 0.47 | - |
| **Fire Injury** | 0.0087 | 0.013 | 0.4 | 0.25 |

**Key Limitations and Sources of Uncertainty**

As discussed throughout this report, Three[3]'s NEI estimates are subject to the following key limitations and sources of uncertainty:

- Because of the design of the national Occupant Survey for which the results are based, the MA-specific results generally apply only to occupants of and measures implemented in low-income single-family homes. These include housing units in small multifamily buildings consisting of between two and four units in total, which is consistent with the PAs' classification of single-family homes in their programs. To the extent possible and at their discretion, however, the PAs may be able to apply the single-family NEIs estimated herein to larger multifamily complexes consisting of "single-family like" units.
- There is considerable uncertainty in the VSL, which ranged from $5 million to $9 million at the time of the national WAP evaluation. An updated value of $9.6 million (2015 dollars) recommended by the USDOT is being applied. A more context sensitive VSL could not be found.
- Except for asthma and reduced CO poisoning, only one (1) occupant per household is assumed to be affected for each NEI.
- The prevalence of asthma in MA could be higher (e.g., larger percentage of communities of color), and asthma analysis does not account for multiple re-admittances.
- For thermal stress, extreme winter and summer weather events that could occur in any given year are unaccounted for. In addition, national (not MA) incidence rates for treatment type and death from thermal stress are applied.
- Only one (1) short-term, high-interest loan per year per household is assumed to be avoided.
- It is assumed that weatherization only reduces the probability of fire to the average probability of fire.[11]

**NMR's Recommendations for Integrating and Applying the Results of Three[3]'s MA LI SF NEI Study**

Following are NMR's recommendations for integrating the results of Three[3]'s MA LI SF NEI study presented in this report into the NEI estimates currently used by the MA PAs (see Section 10.0):

- **Reduced Asthma**—Replace the currently used Health Related NEIs estimate of $19 per year derived from the 2011 NMR study with the asthma NEI value of $9.99 presented in this report (as well as the other health-related NEIs included in this report: reduced thermal stress and fewer missed days at work)
- **Reduced Thermal Stress (both Hot and Cold-Related)**—Replace the currently used Health Related NEI estimate of $19 per year derived from the 2011 NMR study with the cold- and heat-related thermal stress NEI values of $463.21 and $145.93, respectively, presented in this report (as well as the other health-related NEIs included in this report: reduced asthma and fewer missed days at work).
- **Fewer Missed Days at Work**—Replace the currently used Health Related NEIs value estimate of $19 per year derived from the 2011 NMR study with the missed days of work due to illness NEI value of $149.45 presented in this report (as well as the other health-related NEIs included in this report: reduced asthma and fewer missed days at work).
- **Reduced Use of Short-Term, High Interest Loans**—NMR does not recommend counting the NEI value produced by Three[3] in this report as it is not likely a benefit in the

[11] The WAP study evaluated the reduction in fire risk from a wide range of measures, and the $57.48 portion of the total estimated NEI is attributable to measures currently installed by the PAs programs, including the safety inspection, replacement, and/or installation of smoke detectors.

current TRC context, though it could be considered if a different cost were used in the future. Additionally, the PAs could consider further examination of a potential multiplier effect to determine if the benefits accruing to low-income households from bill savings are larger than the corresponding cost in the form of lost PA revenues.

- **Increased Productivity At Home**—The WAP study theorized that the NEI of *increased productivity at home* is attributable to making the weatherized homes more comfortable and conducive to better sleep and therefore likely overlaps with the NEI of improved comfort currently claimed by the PAs.[12] Because of the potential overlap, NMR recommends counting half the NEI value for *increased productivity at home* (to an adjusted value of $18.88).
- **Reduced CO poisoning**—Replace the CO poisoning portion ($6.38 per year) of the Improved Safety NEI derived from the 2011 NMR study with the reduced CO NEI value of $183.30 (one-time PV given the shorter 5-year life of CO detectors) presented in this report.
- **Reduced Risk of Fire and Fire-Related Property Damage**—Replace the fire-safety related NEI of $38.67 per year (for avoided fire deaths, injury, and property damage) currently claimed by the PAs with the fire-safety related NEI value of $57.48 presented in this report.[13]

The substantial increase in the health-related NEIs are largely attribubable to thermal stress NEI and reduced missed days from work. The increase in the thermal stress NEI is principally attributable to the avoided deaths by reducing the chance of an individual being subjected to dangerously cold or hot temperatures (see section 4.0 for an overview of the risks of thermal stress). The risks of thermal stress, including heat and cold-related mortality, are very real and substantial. A recent National Health Statistics Report estimated 2,000 weather related deaths per year in the US from 2006 to 2010 (during the WAP study period) (Berko et al. 2014), with about 31% of these deaths attributed to exposure to heat-related causes and 63% attributed to exposure to excessive cold. The report includes estimates by region, estimating 307 heat and cold related deaths per year in the northeast region. Asuming the deaths are roughly proportionate to the population in each state, there are an estimated 36 cold and heat related deaths per year in Massachusetts, 29 of which were cold-related and eight of which are heat-related (See section 10 for more details).

The substantial increase in the reduced missed days from work NEI is attributable to the WAP study being able to estimate the number of missed days from work (for health-related reasons) and in turn estimate lost wages whereas the 2011 NMR study relied on a single, self-reported estimate of health impacts.

The evaluation team estimated NEIs at the measure level by following the procedures used in the 2011 NMR study. With the exception of CO and Fire, the team assigned a portion of a given NEI value to relevant individual measure based on the average energy bill savings for which the measure was responsible in the 2011 NMR study. The health-related NEIs are apportioned as follows: air sealing (29.9%), duct sealing (0.7%), heating system (27.7%), insulation (25.1%),

[12] The WAP study found evidence of overlap between comfort and sleep through their household survey, finding that warmer, less drafty homes were correlated with better sleep. In addition, the study found that bad sleep is positively correlated with bad physical health days, suggesting potential overlap between the WAP health NEIs and increased productivity (as increased productivity is monetized through reducing productivity losses due to sleep problems).

[13] The WAP study evaluated the reduction in fire risk from a wide range of measures, and the $57.48 portion of the total estimated NEI is attributable to measures currently installed by the PAs programs, including the safety inspection, replacement, and/or installation of smoke detectors.

pipe wrap (5.5%), service to heating or cooling system (6.1%), programmable thermostat (4.8%) and window replacement (0.08%). The NEI for CO is based on CO monitor installation and therefore the entire value is applied to projects that include safety reviews and installation of CO monitors (see Table E.4 for the apportionment of NEIs by measure as well as a comparison of the 2011 NMR and 2016 Three[3] values for each main NEI category). Finally, the analysis in this report is able to estimate the reduction in fire risk on a measure-by-measure basis (See Section 9.0 for more details).

## Table E.4. Apportionment of Household NEI Values to Individual Measures

| | | NEI Category and Recommended Values ($ per unit) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Reduced asthma symptoms | Reduced cold-related thermal stress | Reduced heat-related thermal stress | Fewer missed days at work | Total Health Benefits | Increased home productivity | Total Thermal Comfort (1) | Reduced CO Poisoning | Reduced Home Fires | | Total Improved Safety | |
| | **2011 NMR Value** | | | | | **$19.00** | | **$101.00** | $6.38 (Annual) (3) | | $38.67 (3) | **$45.05** | |
| | **Recommended Value (Three[3] 2016)** | $9.99 | $463.21 | $145.93 | $149.45 | **$768.58** | $18.88 | **$119.88** | $183.30 (One-Time) | | $93.84 | **$183.30 One Time for CO Detectors + $57.48 Annual for Fire and Smoke Detectors** | |
| **Measure** | **Percent of Bill Savings used to Apportion Health and Thermal Comfort NEIs (2)** | Annual | Annual | Annual | Annual | **Annual** | Annual | **Annual** | One-Time | Estimated Risk Reduction (Three[3] 2016) | Annual | **Annual** | |
| Aerator | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | | $0.00 | **$0.00** | |
| Air sealing | 29.9% | $2.99 | $138.66 | $43.69 | $44.74 | **$230.08** | $5.65 | **$35.89** | | 2.39% | $2.24 | **$2.24** | |
| Appliance (refrigerators and freezers) | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | 1.49% | $1.40 | **$1.40** | |
| Door | 0.005% | $0.00 | $0.02 | $0.01 | $0.01 | **$0.04** | $0.00 | **$0.01** | | | $0.00 | **$0.00** | |
| Duct sealing | 0.7% | $0.07 | $3.12 | $0.98 | $1.01 | **$5.17** | $0.13 | **$0.81** | | | $0.00 | **$0.00** | |
| Heating system | 27.7% | $2.77 | $128.45 | $40.47 | $41.44 | **$213.13** | $5.23 | **$33.24** | | 20.11% | $18.87 | **$18.87** | |
| Hot water system | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | 4.73% | $4.44 | **$4.44** | |
| Insulation | 25.1% | $2.51 | $116.41 | $36.67 | $37.56 | **$193.15** | $4.74 | **$30.13** | | 18.54% | $17.40 | **$17.40** | |
| Lighting | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | 2.84% | $2.67 | **$2.67** | |
| Pipe wrap | 5.5% | $0.55 | $25.51 | $8.04 | $8.23 | **$42.34** | $1.04 | **$6.60** | | | $0.00 | **$0.00** | |
| Service to heating or cooling system | 6.1% | $0.61 | $28.33 | $8.93 | $9.14 | **$47.01** | $1.15 | **$7.33** | | 2.87% | $2.69 | **$2.69** | |
| Low flow showerhead | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | | $0.00 | **$0.00** | |
| Programmable thermostat | 4.8% | $0.48 | $22.34 | $7.04 | $7.21 | **$37.07** | $0.91 | **$5.78** | | | $0.00 | **$0.00** | |
| Window | 0.08% | $0.01 | $0.36 | $0.11 | $0.12 | **$0.60** | $0.01 | **$0.09** | | 2.41% | $2.26 | **$2.26** | |
| **Total** | **100%** | $9.99 | $463.21 | $145.93 | $149.45 | **$768.58** | $18.88 | **$119.88** | | 55.38% | $51.97 | **$51.97** | **Annual for Fire** |
| | | | | | | | | | | | | | |
| Smoke Detector Inspection/Replacement/Installation (3) | N/A | | | | | | | | | 5.87% | $5.51 | **$5.51** | **Annual for Smoke Detectors** |
| | | | | | | | | | | 61.25% | **$57.48** | **$57.48** | **Annual for Fire + Smoke Detectors** |
| CO Detector Inspection/Replacement/Installation (3) | N/A | | | | | | | | $183.30 | | | **$183.30** | **One-Time for CO Detectors** |
| | | | | | | | | | | | | $36.98 | (Annual for CO Detectors, 5 yrs) |
| | | | | | | Other Measures to Which the Fire NEI can be Apportioned: | | | | | | | |
| | | | | | | | | | Electrical repair | 16.55% | $15.53 | | |
| | | | | | | | | | Clothes dryer vent repair/replacement | 11.56% | $10.85 | | |
| | | | | | | | | | Chimney repair | 3.52% | $3.30 | | |
| | | | | | | | | | Fans repair/replacement | 2.58% | $2.42 | | |
| | | | | | | | | | Ventilation | 3.68% | $3.45 | | |
| | | | | | | | | | Gas | 0.87% | $0.82 | | |

**Notes:**

(1) The revised value reflects NMR's 2011 estimate of $101 for Thermal Comfort plus half of Three[3]'s estimate for Increased Home Productivity (one-half of $37.75, or $18.88) to account for potential overlap.

(2) With the exception of Reduced CO Poisoning and Reduced Home Fires, the NEIs are apportioned based on the relative percentages of the average bill savings across those measures that are relevant and applicable to each NEI, as analyzed and computed in the 2011 NMR study.

(3) NMR's 2011 estimate for the Improved Safety NEI ($45.05) was based on an analysis of avoided deaths from fire-related CO poisonings ($6.38) and avoided fire deaths, injuries, and property damage (totaling $38.67) due to heating system replacement only. On the other hand, Three[3] is able to estimate the reduction in fire risk on a measure-by-measure basis, the results of which are reflected above. The revised NEI for CO Poisoning is based on CO monitor inspection/replacement/installation and therefore applies as a whole to each measure that involves the safety review, replacement and/or installation of CO monitors (i.e., is not apportioned among measures). The portion of the NEI for Reduced Home Fires attributable to smoke detectors ($5.51) is to be applied to each measure that involves the safety review, replacement and/or installation of smoke detectors.

Table E.5 presents a comparison of the 2011 NMR and 2016 Three[3] values for each main NEI category as well as for two key measures, Weatherization and Heating System Retrofit/Replacement, on both an annual and 20-year PV basis.

**Table E.5. Comparison of 2016 Three[3] and 2011 NMR Estimates on Both Annual and (20 Year) Basis**

| | Annual | | NPV (20 Yrs at 0.44%) | |
|---|---|---|---|---|
| | NMR 2011 | Three[3] 2016 (1) | NMR 2011 | Three[3] 2016 (2) |
| ***By NEI Category*** | | | | |
| Health Benefits | $19.00 | $768.58 | $363.00 | $14,683.78 |
| Thermal Comfort | $101.00 | $119.88 | $1,929.61 | $2,290.22 |
| Improved Safety | $45.05 | $94.46 | $860.68 | $1,281.40 |
| | | | | |
| ***By Key Measure*** | | | | |
| Weatherization, electric or gas (3) | $10.46 | $551.37 | $199.84 | $10,010.70 |
| Heating System Retrofit/Replacement, electric or gas (4) | $50.32 | $307.73 | $961.37 | $5,355.98 |

Notes:
(1) Three[3] 2016 annual NEI estimate for Improved Safety, Weatherization, and Heating System Retrofit includes annual estimate for CO monitors of $38.67 (5-year life).
(2) Three[3] 2016 NPV NEI estimate for Improved Safety, Weatherization, and Heating System Retrofit includes 5-yr (not 20-yr) NPV estimate for CO monitors of $183.30.
(3) Weatherization includes Health, Thermal Comfort, and Safety NEIs apportioned for air sealing, insulation, smoke detectors, and CO detectors.
(4) Heating System Retrofit/Replacement includes Health, Thermal Comfort, and Safety NEIs apportioned for heating system, smoke detectors, and CO detectors.

As shown in Table E.5 the differences between the two sets of results are substantial. The reasons for these substantial differences are as follows:

- The NMR estimates were based on the survey (post-weatherization only) respondents' ability to recognize and report health effects monetized by their willingness to pay for improved health and comfort *relative to their energy bill savings*, whereas the Three[3] estimates are based on the Occupant Survey respondents' self-reported changes in health and household status (as measured from pre- to post-weatherization with a comparison group) and monetized using a more robust set of secondary national and state medical incidence (e.g., applicable types of medical treatment sought) and cost (e.g., by type of insurance coverage and treatment) data.
- The sample size of the Occupant Survey was substantially larger, increasing Three[3]'s ability to detect rare events such as the need for urgent care and potential number of deaths due to thermal stress that could be avoided from weatherization.
- In the Three[3] analysis, the relatively few number of avoided deaths due to thermal stress, CO poisoning, and fire could therefore be monetized assuming a VSL of $9.6 million, which substantially increases the per unit value of the NEIs from the corresponding NMR estimate.

- NMR's survey questions referenced multiple health benefits collectively (colds, flus, asthma, and other chronic health conditions), whereas the Occupant Survey questions targeted each potential health benefit separately (asthma, thermal stress).
- NMR estimated the benefit of improved safety from reduced CO poisoning and fires due to a single measure only (heating system retrofit/replacement), whereas Three[3] estimated this benefit from a wider range of measures using a more robust set of secondary national and state CO and fire incidence data.

# 1.0 Introduction

A recent evaluation of the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) included the assessment and monetization of numerous health and household-related benefits attributable to the weatherization of low-income homes.[14,15] In 2015, the Massachusetts Program Administrators (herein refered to as PAs) contracted Three[3] to evaluate and monetize a sub-set of the health and safety-related non-energy impacts (NEIs) that had been evaluated in the national WAP evaluation. This study entailed the estimation of NEIs specific to the recipients of energy efficiency services residing in income-eligible households in Massachusetts (MA). The MA Low-Income (LI) NEI study included the estimation of the following NEIs:

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

In 2011, the NMR Group[16] had conducted an evaluation study of NEIs attributable to the PAs' residential and low-income programs; that study examined a number of health and safety-related benefits to low-income residents.[17] The PAs are currently using some of the NEIs examined in the 2011 NMR study to claim benefits for applicable programs. The PAs tasked NMR to review the health and household-related benefits study conducted through the national WAP evaluation as well as Three[3]'s additional MA LI SF NEI study. The purpose of NMR's review was to determine to what extent the health and safety NEIs quantified in this WAP-based evaluation overlap with, augment, or supersede the health- and safety-related NEIs previously examined and/or currently claimed by the PAs, and to develop recommendations for integrating the results.[18]

Section 1.0 of this report provides an overview of the health and household-related NEIs component of the national WAP evaluation that was utilized as the foundation for the MA LI SF

[14] Three[3] research staff, under the auspices of Oak Ridge National Laboratory, managed the national WAP evaluation. A complete report presenting findings from this component of the WAP evaluation was published in 2014 and can be found at www.threecubed.org.
[15] A complete description of the methodology is found in: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.
[16] http://www.nmrgroupinc.com/
[17] NMR. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for Massachusetts Program Administrators. (See: http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf)
[18] The Occupant Survey was administered to single family homes including mobile homes and housing units in small multifamily buildings consisting of between two and four units in total, which is consistent with the PAs' classification of single family homes in their programs. Application of NEI results presented in this report to large multifamily buildings is not recommended, given that the building science of large multifamily is unique and the measures installed can be quite different from those installed in single-family and mobile homes. To the extent possible and at their discretion, however, the PAs may be able to apply the single-family NEIs estimated herein to larger multifamily complexes that consist of single-family like units.

NEI study. Section 2.0 presents a description of preliminary processes and statistical analyses leading up to the monetization of the NEIs of weatherization as delivered in Massachusetts. Section 3.0 through 9.0 present the eight NEIs chosen for inclusion in the MA LI SF NEI study.[19] Each NEI section provides an overview of the NEI as it relates to weatherization; a brief summary of the methodology utilized in the national WAP evaluation; and a description of the analysis utilized by Three[3] for the MA LI SF NEI study followed by a discussion. Section 10.0 presents NMR's assessment of Three[3]'s analyses and provides recommendations for the PAs' consideration, on a case-by-case basis.

## 1.1 National WAP Evaluation

Underpinning the research for the national WAP evaluation was a national Occupant Survey of a random and representative sample of weatherized single-family[20] pre- and post-weatherization, along with a comparison group of homes. The Occupant Survey was administered in two phases.[21] In phase 1, the survey was administered to a sample of homes just prior to the energy audits completed in the treatment group households (during calendar year (CY) 2011) (referred to as the Pre-Weatherization Treatment group). The second phase was implemented post-weatherization, approximately 18 months later (during CY 2013) (Post-Weatherization Treatment group). A comparison of these results provides direct insights into the impacts of weatherization because they involved the same group of households surveyed at different points in time.

A group of homes that had already been weatherized one year before the treatment group received weatherization services (Post-Weatherization Comparison) was also surveyed during phase 1. Comparisons between the Pre-Weatherization Treatment and Post-Weatherization Comparison groups also provide useful insights since the data for both groups were collected in the same time period.

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

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

- The physical condition of homes is improved making the homes more livable;
- Respondents experience fewer 'bad' physical, mental health, and sleep/rest days;
- Respondents and other household members suffer fewer persistent colds and headaches;
- There are fewer instances of doctor and emergency department visits, and hospitalizations related to asthma and thermal stress;

[19] Section 4.0, Reduced Thermal Stress on Occupants, combines two NEIs, cold and heat-related thermal stress.
[20] Single-family homes surveyed included mobile homes and small multifamily buildings consisting of between two and four units..
[21] For detailed information on the national Occupant Survey, refer to the Occupant Survey Report: Carroll, D., Berger, J., Miller, C., and Driscoll, C. 2014. National Weatherization Assistance Program Impact Evaluation - Baseline Occupant Survey: Assessment of Client Status and Needs. ORNL/TM- 2015/22, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

- Households are better able to pay energy and medical bills;
- Households are better able to pay for food; and
- Household use of two kinds of short-term, high interest loans (tax refunds and pawn shops) decreases.

To estimate overall program cost effectiveness, it is important to monetize both the energy costs savings and the non-energy benefits attributable to the program. Survey results, estimates of weatherization measures installed (e.g., CO monitors), secondary databases containing national estimates of healthcare costs, and other secondary data and literature were used to monetize these twelve health and household related co-benefits of DOE's WAP:

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

These NEIs were chosen for monetization because the evaluation collected data pertinent to measuring the direct outcomes and/or monetizable outcomes related to each NEI. For example, the national Occupant Survey asked respondents pre- and post-weatherization and a comparison group post-weatherization about thermal stress, asthma symptoms and medical treatment, improvements in sleep, missed days at work, etc. The evaluation also collected information on measures installed by WAP in a representative sample of homes that was used to estimate reduced carbon monoxide poisonings and home fires.

It should be noted that, in general, homes do need to receive a full complement of major weatherization measures (e.g., air sealing, insulation, HVAC replacement/repair) to generate the types of NEIs described. Findings from the national WAP evaluation showed that enough homes received a sufficient level of measures to yield significant non-energy benefits. It should also be noted that while every household is expected to receive energy cost reduction benefits from weatherization, not every household is expected to receive the health and household-income related benefits identified through the national WAP evaluation. For example, only a subset of households will experience thermal stress events in the absence of home weatherization, so fewer households are available to receive this benefit than will experience energy cost reductions.

### 1.1.1 Discussion—Sample Sizes and Statistical Significance

There are a multitude of health studies conducted that consist of small sample sizes that represent respectable research. During the data analysis design phase, Three[3] did face the issue of whether sample sizes were large enough to capture rare events. For example, the Occupant Survey asked questions about fires and CO poisoning pre- and post-weatherization. The responses indicated that both were very rare given our sample size, and national data supports these conclusions. However, preventing fires and CO poisoning are policy relevant and important NEIs of weatherization. We therefore believe that estimating the monetized benefits of reducing fires and CO poisoning are worthwhile given that deaths could be prevented. So, in these two instances, data collected through the national evaluation on weatherization measures installed

(e.g., various measures that map specifically to fire ignition risks or serve as fire suppressors), national Occupant Survey responses for CO monitors installed that may reduce the incidence of CO poisoning, along with secondary data were relied upon to anchor the methodologies.

In the case of thermal stress, had the sample size been larger (and possibly included large multifamily units) one could argue that findings would have been more statistically robust than they were. Again, the magnitude of the change in medical needs from pre- to post-weatherization is enough to be policy relevant.

Hospitalizations for asthma are also considered rare events within the general population, which is where the analysis began for the asthma sample; emergency department (ED) visits are less rare and were therefore observed more often than hospitalizations in the pre-weatherized treatment group. The improvement in asthma morbidity as measured by ED visits in the asthma sample was determined to be statistically significant. Although a reduction in hospitalizations for asthma was observed post-weatherization, it was not statistically different from zero. It is believed this is a result of a small sample size and a rare event.

Additionally, health and safety-related findings are augmented by anecdotal evidence offered by the human stories shared by the weatherization agencies and by recipients of the programs themselves. Ultimately, these benefits were analyzed from multiple angles. Triangulation as a research method (i.e., arriving at conclusions by using multiple sources of information) is common within the social sciences. Because the benefits selected for analysis were approached in this way, the Three[3] researchers were able to confidently monetize changes in occurrences even if they did not achieve statistical significance for the reasons explained above. A national panel of experts reviewed all methodologies and assumptions—the panel did not question the validity of any of the NEIs nor were the findings dismissed as inconsiderable as there was a clear indication of health improvements.

## 1.2 Presentation of Findings

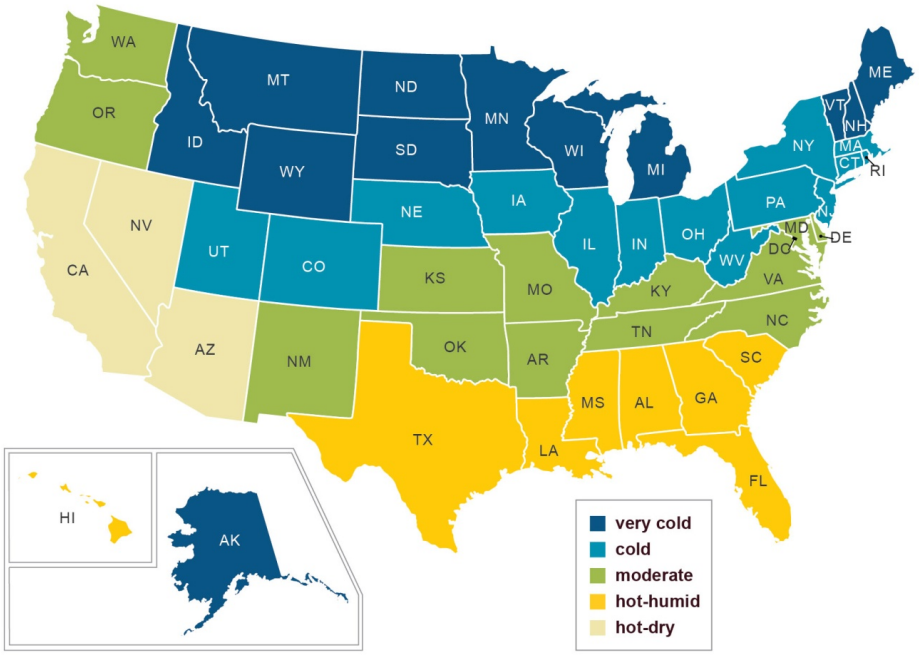
For the national WAP evaluation, the estimated NEI values were presented on a dollar per weatherized unit basis, broken down by both societal and household benefit components as well as including estimated values for both with and without the value of lives saved. The present value (PV) of the benefits was estimated over a ten-year time horizon[22], using the discount rate of 0.1% published by the Office of Management and Budget for Fiscal Year (FY) 2013. The estimates were presented in three tiers. Tier 1 estimates were based on observed monetizable outcomes attributable to weatherization (i.e., observed through the national Occupant Survey, pre- and post- weatherization with a comparison group) and highly reliable cost data. Tier 2 and 3 estimates were established to have underlying sound methodologies, but may have lacked direct observations of improved health or well-being (e.g., based on counts of installed CO monitors rather than on survey reports of fewer CO poisonings post-weatherization) and/or required relatively more assumptions.

[22] With the exception of the non-energy benefit of installing CO monitors, where present value was calculated over a more conservative 5-year period as the lifespan of CO monitors generally remains effective for an average of five years.

# 2.0 Massachusetts Low-Income Health- and Safety-Related Non-Energy Impacts

Data for households located in the cold region of the U.S. (comparable to the MA climate) (Figure 2.1) were mined from survey findings from the national Occupant Survey administered to recipients of DOE's WAP, as well as to a comparison group. Data for households located in the very cold region of the U.S. were also considered for inclusion. Combining the cold and very cold climate regions to increase statistical significance was explored. The inclusion of the very cold climate zone into the sample versus the utilization of regional or national data for the cohort sample for select NEIs, was discussed with the project team.

**Figure 2.1. Climate Regions**




The project team decided consistency with respect to climate region for the cohort sample was preferred. For most of the NEIs, the size of the cold climate region sample was more than sufficient, and combining cold and very cold climate regions did not increase the statistical significance by much, if any. Furthermore, in a few instances, the results between the two climate zones were too different to be able to defend their combination. Table 2.1 provides the recommendations and reasoning for cohort sample selection.

**Table 2.1. Recommendations and Reasoning for Cohort Sample Selection**

| NEI | Recommendation for Cohort Sample Selection | Reasoning |
|---|---|---|
| **Asthma Symptoms** | **National** | Asthma prevalence does not vary significantly by climate region. In order to capture the potential impacts, a more robust sample size would be beneficial. |
| **Medical Attention – too cold** | **Cold Climate Region** | Impacts are directly related to climate region. |
| **Medical Attention – too hot** | **Cold Climate Region** | Impacts are directly related to climate region. |
| **Missed Days of Work (avg. # days)** | **Cold Climate Region** | Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values. |
| **Use of Short Term Loan** | **Cold Climate Region** | Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values. |
| **Respondents That Did Not Get Enough Rest or Sleep Previous Month** | **Cold Climate Region** | Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values. |
| **Have Working CO Monitor** | **Cold Climate Region** | Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values. |
| **Have Smoke Detector** | **Cold Climate Region** | Sample size is more than sufficient. There is no value in combining cold and very cold climate regions with respect to p-values. |

## 2.1 Descriptive Statistics

The tables below present data for the pre- and post-weatherization treatment groups and the post-weatherization comparison group. For all NEIs, with the exception of asthma, data is presented for the cold climate region only—for the asthma NEI, national level data is presented. Cohort sample sizes by the cold climate region for seven of the eight NEIs are included in Table 2.2, with asthma sample sizes in Table 2.3. Table 2.4 characterizes the cohort sample with respect to housing and demographics, and Table 2.5 and 2.6 present frequencies from the Occupant Survey for health and household related variables. Tables 2.7-2.12 present the reported decrease in occurrence (in %), and the statistical significance of these values, for thermal stress, poor rest/sleep, use of short-term loans, missed days of work, home fires, and CO poisoning. Table 2.13 presents this same data for the national asthma sample cohort.

**Table 2.2. Cohort Sample Sizes for Cold Climate Region**

| | Sampled Groups | | |
|---|---|---|---|
| | **Pre-Wx Treatment (Survey Phase 1)** | **Post-Wx Treatment (Survey Phase 2)** | **Post-Wx Comparison (Survey Phase 1)** |
| **Cold Climate Region** | 318 | 190 | 331 |

**Table 2.3. Sample Sizes for Respondents That "Have Been Told They Have Asthma" and Those That "Still Have Asthma"**

| | Sampled Groups | | |
|---|---|---|---|
| | **Pre-Wx Treatment (Survey Phase 1)** | **Post-Wx Treatment (Survey Phase 2)** | **Post-Wx Comparison (Survey Phase 1)** |
| **National – All** | 94 | 61 | 123 |

**Table 2.4. Housing and Demographic Characteristics**

| | Sampled Groups | |
|---|---|---|
| | **Pre-Wx Treatment (Survey Phase 1)** | **Post Wx Comparison (Survey Phase 1)** |
| **% Single-Family Homes*** | 75% | 80% |
| **Heating Fuel** - Natural Gas** | 61% | 57% |
| **Heating Fuel - Electric** | 11% | 10% |
| **Heating Fuel – Fuel Oil** | 12% | 22% |
| **Heating Fuel – Propane** | 7% | 6% |
| **Heating Fuel – Kerosene** | 7% | 5% |
| **Heating Fuel – Wood** | 3% | 0.3% |
| **Age Respondent (in yrs.)** | 56 | 68 |
| **Household Size** | 2.6 | 2.2 |
| **Respondent Employed** | 33% | 34% |
| **Home in Rural Area** | 29% | 29% |
| **Respondent Married** | 34% | 34% |
| **Respondent Education – High School** | 41% | 42% |

*Mobile homes and small multi-family (2-4 units) constituted the remaining percent.
**Percentages of heating fuel types might not total 100% due to rounding.

Statistical tests were conducted to assess the differences between the pre-weatherization treatment and post-weatherization treatment and comparison groups. Asterisks found in the second and third columns of Table 2.5 and Table 2.6 indicate whether a statistically significant difference exists between the pre-weatherization treatment and post-weatherization treatment groups and the pre-weatherization treatment and post-weatherization comparison groups, respectively.

**Table 2.5. Health and Household Variables Related to Select NEIs (Cold Climate Region)**

| | Sampled Groups | | |
|---|---|---|---|
| | **Pre-Wx Treatment (Survey Phase 1)** | **Post-Wx Treatment (Survey Phase 2)** | **Post-Wx Comparison (Survey Phase 1)** |
| **Medical Attention – too cold** | 4.1% | 2.6% | 1.8% |
| **Medical Attention – too hot** | 3.8% | 1.1% | 0.9%* |
| **Missed Days of Work (ave. # days)** | 10.6 | 4.1 | 9.1** |
| **Used Short Term Loan** | 18% | 9% | 13%** |
| **Respondents That Did Not Get Enough Rest or Sleep Previous Month** | 68% | 66% | 60%* |
| **Have working CO Monitor** | 54% | 81%*** | 90%*** |
| **Have Smoke Detector** | 94% | 97% | 98%*** |

*** p<.001, ** p<.01 and *p<.05

**Table 2.6. Health Variables Related to Asthma (National Sample)**

| | Sampled Groups | |
|---|---|---|
| | **Pre-Wx Treatment (Survey Phase 1)** | **Post-Wx Treatment (Survey Phase 2)** |
| **Asthma Emergency Department** | 15.8% | 4.3%* |
| **Asthma Hospitalization** | 13.7% | 10.6% |
| **Asthma Symptoms < 3 months ago (i.e. high-cost patient)** | 70.5% | 58.7% |

*** p<.001, ** p<.01 and *p<.05

## 2.2 Monetization Approach

For six of the eight NEIs addressed by this research, the results of the national Occupant Survey were used as the basis for the monetization approaches as sample size was sufficient to indicate observable impacts from pre- to post-weatherization. For two of the NEIs, carbon monoxide (CO) poisoning and fire prevention, the data sources were different. The Occupant Survey did include questions specific to instances of CO poisoning and home fires; however, these events are relatively infrequent. Instead, data was collected from local weatherization agencies on the number of CO monitors installed that could reduce the probability of CO poisoning, and the number of smoke detectors installed, as well as other weatherization measures that could reduce the probability of home fires.

The tables for CO monitors and smoke detectors contained in this piece are based on data related to the number of installations of these measures, as subjectively reported by the respondents (weatherization agencies). The data, which were collected pre- and post-weatherization, indicated generally statistically significant changes from pre- and post-weatherization for these measures. The data from the local weatherization agencies were used

instead of the Occupant Survey data because the former were judged to be more statistically robust, with a much higher sample size.

The decrease in occurrence for all NEIs, with the exception of asthma, between pre- and post-treatment groups and between pre- treatment and post-comparison groups was calculated (i.e., an average of the differences) (see Equation 1). This approach was utilized to make the best use of the collected data. The equation utilized for asthma will be presented in the next section.

*Equation 1. [(Pre-Wx Treatment – Post-Wx Treatment) + (Pre-Wx Treatment – Post-Wx Comparison)] / 2*

In Tables 2.7 – Table 2.12, column 1 presents the Pre-Wx Treatment – Post-Wx Treatment values (decreased occurrence), column 2 presents the Pre-Wx Treatment – Post-Wx Comparison values (decreased occurrence), and column 3 presents the value resulting from the application of Equation 1, equaling the total decrease in occurrence. Statistical significance (p-value) was explored, utilizing the appropriate statistical analyses, and is presented within the tables as well.

**Table 2.7. Thermal Stress**

| | Decrease in Occurrence: Difference between Pre-Wx (N=318) and Post-Wx Treatment (N=190) | Decrease in Occurrence: Difference between Pre-Wx Treatment (N=318) and Post-Wx Comparison (N=331) | Total Decrease in Occurrence |
|---|---|---|---|
| **Medical Attention – too COLD** | 1.5% | 2.3% | 1.9% |
| **Exact Sig. (2-tailed)*** | .754[a] | .104[b] | |
| **Medical Attention – too HOT** | 2.7% | 2.9% | 2.8% |
| **Exact Sig. (2-tailed)*** | .125[a] | .018[b] | |

*Statistically significant if p<.05; [a.]McNemar Test; [b.]Fisher's Exact Test

**Table 2.8. Missed Days of Work**

| | Decrease in Occurrence: Difference between Pre-Wx (N= 92) and Post-Wx Treatment (N= 60) | Decrease in Occurrence: Difference between Pre-Wx Treatment (N= 92) and Post-Wx Comparison (N=89) | Total Decrease in Occurrence |
|---|---|---|---|
| **Reduction in Missed Days of Work Past Year (Days)** | 6.5 | 1.5 | 4.0 |
| **Paired Samples (2-tailed)** | .891 | - | - |
| **One-way ANOVA** | - | .013 | - |

*** p<.001; ** p <.01; * p<.05

**Table 2.9. Use of Short-Term Loans**

| | Decrease in Occurrence: Difference between Pre-Wx (N=314) and Post-Wx Treatment (N= 186) | Decrease in Occurrence: Difference between Pre-Wx Treatment (N= 314) and Post-Wx Comparison (N=327) | Total Decrease in Occurrence |
|---|---|---|---|
| **% Reduction in Reporting Used at Least One Short-Term Loan in Previous Year** | 8.3% | 4.6% | 6.45% |
| **Exact Sig. (2-tailed)*** | .55[a] | .002[b] | - |

*Statistically significant if p<.05; [a.]McNemar Test; [b.]Fisher's Exact Test

**Table 2.10. Poor Sleep/Rest**

| | Decrease in Occurrence: Difference between Pre-Wx (N= 315) and Post-Wx Treatment (N=181) | Decrease in Occurrence: Difference between Pre-Wx Treatment (N= 315) and Post-Wx Comparison (N= 326) | Total Decrease in Occurrence |
|---|---|---|---|
| **% Reduction in Reports of # of Days in Previous Month Slept/Rested Poorly** | 2.0% | 8.0% | 5.0% |
| **Exact Sig. (2-tailed)*** | .511[a] | .04[b] | - |

*Statistically significant if p<.05; [a.]McNemar Test; [b.]Fisher's Exact Test

**Table 2.11. Have CO Monitor**

| | Decrease in Occurrence: Difference between Pre-Wx (N= 312) and Post-Wx Treatment (N=190) | Decrease in Occurrence: Difference between Pre-Wx Treatment (N=312) and Post-Wx Comparison (N=327) | Total Decrease in Occurrence |
|---|---|---|---|
| **% Increase in Having a CO Monitor** | 27% | 36% | 29% |
| **Exact Sig. (2-tailed)*** | .000[a] | .000[b] | - |

*Statistically significant if p<.05; [a.]McNemar Test; [b.]Fisher's Exact Test

**Table 2.12. Have Smoke Detector**

| | Decrease in Occurrence: Difference between Pre-Wx (N=317) and Post-Wx Treatment (N=189) | Decrease in Occurrence: Difference between Pre-Wx Treatment (N= 317) and Post-Wx Comparison (N= 330) | Total Decrease in Occurrence |
|---|---|---|---|
| **% Increase Having a Smoke Detector** | 3% | 4% | 3.5% |
| **Exact Sig. (2-tailed)*** | .180[a] | .112[b] | - |

*Statistically significant if p<.05; [a]McNemar Test; [b]Fisher's Exact Test

As mentioned previously, the equation (Equation 2) utilized for the monetization approach for the asthma NEI was different from the other seven NEIs due to the diverging sample characteristics between the treatment and comparison groups (see Section 3.1) and is as follows:

*Equation 2. Pre-Wx Treatment – Post-Wx Treatment*

Table 2.13 presents the reported decrease in occurrence (in %), and the statistical significance of these values from similar statistical analyses utilized previously, as well as from a logistic regression model.

**Table 2.13. Asthma**

| | ED Visit from Asthma (Decrease in Occurrence) | Hospitalization from Asthma (Decrease in Occurrence) | High Cost Asthma Patient (Decrease in Occurrence) |
|---|---|---|---|
| **Difference between Pre-Wx and Post-Wx Treatment (%)** | 11.5% | 3.1% | 11.8% |
| **N[23]** | 47 | 47 | 46 |
| **Fisher's Exact Test (p-value)** | .445 | .154 | .002 |
| **McNemar Test** | 1.000 | .727 | .388 |
| **Logistic Regression (n=130)** | .035* | NA | NA |

*The results from the logistic regression analysis indicate that weatherization is associated with fewer visits to the ED for asthma.

## 2.3 Modifications to Monetization Methods

A variety of modifications were made to the methodology and to the values of inputs utilized for the national NEI monetization models. In order to conduct a state-level analysis, inputs need to reflect the context. Each NEI section includes a listing of adjustments made, followed by the adjusted value of the input. Modifications that were applied to all NEIs are as follows:

[23] The number of respondents who answered the survey questions referred to in Table 2.13 was less than the number of respondents who answered the questions referred to in Table 2.3.

- Only per unit/household impacts were monetized, and any values related to program-wide impacts included in the equations utilized for the national WAP evaluation were removed (i.e., number of homes treated by WAP in PY 2008).
- The discount rate was adjusted from a very low Office of Management and Budget (OMB) rate of 0.1% to a twenty-year discount rate of 0.44%.[24,25]
- The Value of Statistical Life (VSL) was updated from $7.5M[26] to the U.S. Department of Transportation's (DOT) recommended value for 2016 of $9.6M (See Section 2.3.1).
- Lastly, per recommendations of the MA NEI study project team, the VSL associated with avoided deaths was applied as a household benefit rather than a societal benefit.[27]

### 2.3.1 Avoided Death Benefits

To monetize the benefit of avoided deaths from thermal stress, CO poisoning, and fire, the VSL was adjusted and updated from the $7.5M (2008 dollars) used in the national WAP evaluation to $9.6M (2015 dollars), as published in the DOT forthcoming guidance document for 2016.[28] The DOT issues annual updates to the VSL to adjust for changes in prices and real incomes. Federal agencies including DOT and U.S. Environmental Protection Agency (EPA) use the VSL to assess the benefits of their regulations or policies intended to reduce deaths or fatalities (e.g., from traffic accidents or adverse environmental events/conditions). The last known VSL published by the EPA is $7.4M (2006 dollars), which is to be updated to the year of analysis.[29] An article published in *Risk Analysis* provides an overview of VSL application in federal regulatory analyses and states: 1) EPA's and DOT's estimates have become remarkably similar; both now use central VSL estimates somewhat above $9 million; 2) this increasing similarity appears to result at least

[24] The national WAP evaluation used the ten-year real treasury interest rate for 2013 (0.1%) from Office of Management and Budget (OMB) to calculate the present value (PV) of the total discounted savings for all NEIs.
[25] The use of a 0.44% discount rate over a period of twenty years to calculate the PV is consistent with the discount rate and the measure life for low-income weatherization used in the MA PAs' Three-Year 2016-18 Plan.
[26] Value of human life, or as economists refer to it as, the Value of Statistical Life (VSL) is a measure used to compare regulatory costs to benefits. At the time of the WAP evaluations, the U.S. government agencies were using values ranging from $5-9 million in regulatory cost-benefit analysis. The WAP National Evaluation used a conservative VSL of $6 million (2000 dollars) adjusted for inflation to $7.5 million in 2008 dollars. See OMB Circular A-4 for more discussion on VSL.
[27] EPA does not explicitly state that the effect of the VSL costs and benefits should be applied as societal or household impacts; this lack of guidance has resulted in conflicting schools of thought on this matter. Based on consultation with health economists, the WAP National Evaluation chose to apply avoided costs as a societal benefit. However, based on additional research, it is clear that VSL estimates are based on the value that individuals' place on reducing their own mortality risk. Thus, for this study, it was decided to categorize VSL as a household benefit (See Section 2.3.1 for more detailed information on this decision).
[28] DOT's annual VSL guidance for 2016 is forthcoming (Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analysis). In the interim, the updated VSL is published in DOT's Benefit-Cost Analysis (BCA) Resource Guide, updated March 1, 2016, available at https://www.transportation.gov/sites/dot.gov/files/docs/BCA%20Resource%20Guide%202016.pdf. DOT's 2015 guidance document, dated June 17, 2015, is available at https://www.transportation.gov/sites/dot.gov/files/docs/VSL2015_0.pdf.
[29] EPA. Mortality Risk Valuation. Available at https://www.epa.gov/environmental-economics/mortality-risk-valuation#whatisvsl.

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). [30]

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

Discussion arose regarding whether a VSL more specific to the low-income population has been developed and can therefore be applied in this study. Age-specific VSLs, which have been studied, can be related, in part, to income level. However, the literature shows "that the relationship between age and WTP (willingness to pay) for mortality risk changes is ambiguous" and the empirical evidence and state preference results are mixed (EPA 2010). [31] Furthermore, for policy reasons and because DOT regulations typically affect a broad cross-section of people, DOT guidance explicitly assigns a single, nationwide VSL regardless of age, income, or other distinct characteristics of the affected population, the mode of travel, or the nature of the risk." EPA similarly applies a single VSL value and had discontinued its use of age adjustments (lower VSL for older age groups) after its "review of emerging research suggested that the effects of age on VSL were highly uncertain" (Robinson & Hammitt 2015). [32] Regardless if VSLs had been developed specific to age-groups or income-level, the study team decided that any such adjustment would reflect a devaluation of life in both circumstances and therefore seemed unethical.

Finally, the benefit of avoided deaths (except for firefighters) is being applied in this MA-specific study as a household benefit. Cost benefit analyses conducted at the federal level do not typically distinguish benefits accrued to individuals/households apart from society as a whole. In accordance with MA state guidelines for assessing the cost effectiveness of the PAs' energy efficiency programs, the avoided death benefits assessed in this study are consistent with the allowable class of benefits that accrue to program participants/households.[33] For example, the PAs currently apply a benefit for avoided fire and carbon monoxide deaths attributable to its low-income program for heating system replacement and repair, as estimated in the 2011 NMR NEI study, as a benefit to program participants. Conversely, the avoided death benefits estimated herein do not appear to be in the same class as the "societal" NEIs that had been assessed and quantified in the 2011 NMR study, but subsequently disallowed for use by the State because they do not accrue to program participants. These disallowed "societal" NEIs include those associated with the benefits of reducing the need for foreign energy imports; avoiding landfill space and recycling; and increasing jobs, business sales, and gross state product.[34]

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[30] Robinson, Lisa A. and Hammitt, James K. "Research Synthesis and the Value per Statistical Life," *Risk Analysis*, Vol. 35, No. 6, 2015, p. 1088.
[31] USEPA. Appendix B: Mortality Risk Valuation Estimates, *Guidelines for Preparing Economic Analysis*, December 2010, p. B-5., available at https://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf.
[32] Robinson, Lisa A. and Hammitt, James K. "Research Synthesis and the Value per Statistical Life," *Risk Analysis*, Vol. 35, No. 6, 2015, p. 1090.
[33] Massachusetts Department of Public Utilities, Section 3.4.4.1, "Energy Efficiency Program Cost-Effectiveness," from Guidelines for the Methods and Procedures for the Evaluation and Approval of Energy Efficiency Plans and Energy Efficiency Reports, revised January 31, 2013.
[34] Massachusetts Department of Public Utilities, D.P.U. 12-100 through D.P.U. 12-111, Order of Three-Year Energy Efficiency Plan for 2013 through 2015, January 31, 2013, pp. 105-106.

The project team also explored whether a different VSL value is being used by regulatory agencies in MA (e.g., MA Department of Transportation (MADOT), MA Department of Environmental Protection (MADEP)), but did not find any in the published literature or through inquiries made to agency personnel. However, the project team did find a 2010 MADOT publication that references the USDOT's 2009 VSL to monetize the value of accidental traffic deaths that can be prevented through improvements to freight infrastructure and operations in the Commonwealth.[35]

## 2.4 Presentation of Findings

The presentation of estimated NEI values for the MA LI SF NEI study are similar to the national WAP evaluation in that values are presented on a per weatherized unit basis, broken down by their societal and household benefit components, a PV estimate of the benefits is provided, and estimates are presented in three tiers. The main contributors to these estimates are: avoided deaths from CO poisoning, fire, and thermal stress; avoided hospitalizations and ED visits related to these three areas as well as asthma-related symptoms; and disposable income gains from fewer missed days at work.

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

# 3.0 Reduced Asthma

Weatherization has the potential to act as a multi-component intervention mitigating the severity and incidence of asthma episodes by addressing multiple triggers in the home environment. Weatherization reduces the number and potency of home-based environmental asthma triggers, resulting in fewer asthma symptoms, direct medical costs, and indirect costs. This analysis explores the transferability of the monetized benefits of weatherization delivered through WAP to the Massachusetts PAs' weatherization programs relevant to this study.

Weatherization measures address multiple evidence-based indoor environmental triggers (e.g., mold, cockroaches, mice, dust, other particulate matter, and by-products of combustion from gas cooking stoves and portable unvented heaters) covered by public health campaigns and community health education programs tasked with reducing asthma morbidity.

## 3.1 National WAP Evaluation—Summary of NEI Analysis

Tables 3.1 and 3.2 characterize the national WAP population with regards to asthma prevalence. Respondents were initially asked if they had "*ever* been told by a physician" that they have asthma. If the respondent answered in the affirmative, they were then asked if they *still* have asthma. The results from the survey indicate that 16.8% of adults in the WAP eligible population have asthma. Descriptive frequencies were generated for all respondents who reported still having asthma in either phase of the survey, and for those who responded to both pre- and post-weatherization surveys.

Due to the diverging sample characteristics between treatment and comparison groups, changes in responses pertaining to asthma control and associated urgent care utilization were monetized using the treatment group responses only pre- and post-weatherization. The national Occupant Survey posed these two questions to the respondent reporting current asthma diagnosis:

*During the past 12 months did you have to stay overnight in the hospital because of asthma?_____*

*Not counting hospitalizations, during the past 12 months, did you go to an emergency room because of asthma?_____*

Tables 3.1 and 3.2 present the final descriptive frequencies for the monetization of these benefits attributed to weatherization.

**Table 3.1. Reduction in Asthma Related ED Visits for All Respondents Reporting Current Diagnosis of Asthma**

| % of Respondents Reporting Visit to ED due to asthma[36] | ED Visit | Difference |
|---|---|---|
| **Whole Asthma Sample-Treatment Group (Pre-Wx; n=95)** | 15.8% | (-) 11.5%* |
| **Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=47)** | 4.3% | |

*** p<.001; ** p <.01; * p<.05

[36] The number of respondents who answered this survey question is one more than the number in Table 2.3, One additional survey respondent answered this question, but was not on record for answering the survey questions in Table 2.3.

**Table 3.2. Reduction in Asthma Related Hospitalizations for All Respondents Reporting Current Diagnosis of Asthma**

| % of Respondents Reporting Hospitalization due to asthma[37] | Hospitalization | Difference |
|---|---|---|
| **Whole Asthma Sample-Treatment Group (Pre-Wx; n=95)** | 13.7% | (-) 3.1% |
| **Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=47)** | 10.6% | |

*** p<.001; ** p <.01; * p<.05

The non-energy benefit attributable to fewer ED visits was monetized as follows:

*Benefit = (number of persons served by WAP in PY 2008) * (asthma prevalence for adults and children)[38] * (reduction in ED visits) * (frequency of re-admittance (adults and children)) * (average hospital costs (adults and children))*

The non-energy benefit attributable to fewer hospitalizations was monetized as follows:

*Benefit = (number of persons served by WAP in PY 2008) * (asthma prevalence for adults and children) * (reduction in hospitalizations) * (frequency of re-admittance (adults and children)) * (average hospital costs (adults and children))*

As stated, in addition to averted medical costs associated with hospitalization and ED visits due to asthma, there is sufficient evidence to suggest that weatherization acts in part as a home-based multi-trigger or multi-attribute asthma reduction program providing additional benefits beyond the changes in utilization of urgent care captured in the survey. These benefits are observed through other direct medical costs (i.e., reduced prescribed medicines, office and clinic visits, and hospital outpatient) and indirect costs (i.e., reduced housekeeping loss, loss of work and school productivity, and restricted activity).

In efforts to monetize potential reductions in averted medical costs and indirect costs outside of urgent care treatment provided through ED visits and hospitalizations, a methodology was developed to identify individuals as "high-cost" asthma patients pre-weatherization, but then identified as "low-cost" asthma patients post-weatherization. Based on respondents' reports of the last time they had asthma symptoms, compared to those who reported ED visits or hospitalizations due to asthma, a framework was developed to identify respondents as either high or low-cost asthma patients. Those who reported last having asthma symptoms less than three months ago were counted as high-cost asthma patients and those who reported last having asthma symptoms greater than three months ago were identified as low-cost asthma patients. Table 3.3 provides the reduction in high-cost patients in the treatment group whole asthma sample (11.8%). This reduction in percentage was used for the monetization of the benefit.

[37] The number of respondents who answered this survey question is one more than the number in Table 2.3, One additional survey respondent answered this question, but was not on record for answering the survey questions in Table 2.3.

[38] Adult prevalence used for the WAP eligible population was estimated using self-reported survey data (16.8%). Child prevalence was estimated based on national statistics—10.1% for poor white children and 16.0% for poor non-hispanic black children. The portion of WAP population receiving services was estimated using demographic data from the occupant survey: 19% non-hispanic black and 81% other. The benefit is computed and monetized assuming both adults and children (not just the adult head of household) are affected by asthma in a given household based on their respective prevalence rate and medical costs.

**Table 3.3. Reduction in High-Cost Patients**

| % of Respondents Identified as High-Cost Asthma Patient by Group and by Sample[39] | High-Cost | Difference |
|---|---|---|
| **Whole Asthma Sample-Treatment Group (Pre-Wx; n=93)** | 70.5% | (-) 11.8% |
| **Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=46)** | 58.7% | |

*** p<.001; ** p <.01; * p<.05

The non-energy benefit from a reduction in direct medical costs outside of ED visits and hospitalization, and from a reduction in indirect costs associated with high-cost asthma patients within the whole asthma sample treatment group was monetized as follows:

*Benefit = (number of persons served by WAP in PY 2008) * (asthma prevalence for adults and children) * (reduction in high-cost patients) * (difference in high and low cost patients after extracting the ED visit and hospitalization costs already claimed))*

## 3.2 MA LI SF NEI Study

Changes in asthma-associated healthcare utilization and improved control were drawn from the entire national subsample of survey respondents reporting current asthma diagnosis and not for the cold and/or very cold regions only. Although indoor environmental asthma triggers are often specific to geographic and climate regions, and diverse across housing types, differences in overall prevalence within the general population by region are negligible. It was also determined that the estimated higher percentage of those with asthma found in the WAP eligible population will be used for estimating the monetized value of the NEI for this study instead of using Massachusetts state-level asthma prevalence for its general population. We apply the higher WAP-based asthma prevalence rate because previous findings suggest that households applying for services are motivated by energy affordability issues, as well as dwelling quality issues relatable to poor health status.

Final consideration was given to the use of national WAP evaluation outcomes related to changes from high to low-cost asthma patients post-weatherization and whether or not this issue had relevance in Massachusetts. According to the "2014 Costs Trends Report"[40] produced by the Health Policy Commission (HPC) in Massachusetts, asthma is indeed considered a key clinical condition for persistently high-cost patients.

For the above-mentioned reasons, methodologies (Section 3.1) for calculating the asthma-related benefits for WAP were employed for this study with the exception of the inclusion of reductions in indirect costs. Indirect costs were not used as inputs for this model due to the risk of double counting savings generated from other NEIs in this study (i.e. fewer missed days of work, increased productivity at home due to increased sleep).

[39] The number of respondents included in this analysis is fewer than the number referred to in Tables 2.3, 3.1 and 3.2 due to criteria filters used for high-cost patient analysis (i.e. still have asthma, answered survey questions related to asthma symtoms).

[40] Health Policy Commission. 2014 Cost Trends Report. Boston, MA 2014; http://www.mass.gov/anf/budget-taxes-and-procurement/oversight-agencies/health-policy-commission/2014-cost-trends-report.pdf

The new equation for calculating the direct medical savings (other than from reduced ED and hospitalizations) of the total asthma benefit is as follows:

*Benefit = (number of persons served by WAP in PY 2008) * (asthma prevalence for adults and children[41] * (reduction in high-cost patients) * (difference in high and low cost patients after extracting the ED visit, hospitalization, and indirect costs already claimed))*

Average state-level costs for asthma-related hospitalizations and ED visits were identified for FY 2009-2013 and used as inputs for the model.[42] To estimate impacts from changes in other direct medical costs, the WAP 2008 estimate was adjusted to 2014 costs. The out-of-pocket (OOP) costs were estimated to determine the household benefit, with the remaining medical costs incurred by private insurers, Medicaid, and Medicare considered as societal benefits. The HPC report (2014) suggests that, on average, commercially insured individuals with chronic health conditions spend approximately seven percent OOP of the total allowable healthcare costs incurred for that illness. This percentage was input as the household portion of the total asthma benefit calculated for the percentage of the population with commercial insurance and those uninsured (~ 43%).

## 3.3 Findings

Table 3.4 below presents the estimates of this NEI for the MA LI SF NEI study. This table includes the combined annual impacts per weatherized unit and PV of the impacts per unit, assuming a twenty-year life span of the weatherization measures, for reductions in ED visits, hospitalizations, and other direct healthcare costs.

**Table 3.4. Estimated Impacts of Reduced Asthma-related Costs[43]**

| | Annual Per Unit Benefit | PV Per Unit Benefit |
|---|---|---|
| **Households** | $9.99 | $190.92 |
| **Society** | $322.01 | $6,151.96 |
| **Total** | **$332.00** | **$6,342.88** |

**Inputs**

- National WAP evaluation findings on changes in asthma-related health status and healthcare utilization were used;
- Average cost for asthma-related hospitalization per adult for 2009-2013 was $8,381 resulting in an estimated savings of $82 per weatherized household;

[41] Adult and child prevalence used for the WAP eligible population was used for the MA LI NEI Study and was similarly computed and monetized assuming both adults and children (not just the adult head of household) are affected by asthma in a given household based on their respective prevalence rate and medical costs.

[42] Discharge data containing asthma costs for inpatient and ED admissions (without complication or comorbidity (CC)) for all age categories and payer types were retrieved from the Center for Health Information and Analysis (CHIA); http://www.chiamass.gov/utilization-analysis/. CHIA is an agency of the Commonwealth of Massachusetts.

[43] For individuals/occupants covered by Medicaid or Medicare, all of the avoided medical costs was categorized as a societal benefit. For individuals/occupants covered by private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (7% as copayments or deductibles) were categorized as a household benefit. For individuals/occupants that are "uninsured," the OOP costs (7% of total medical costs) were categorized as a household benefit.

- Average cost for asthma-realted hospitalization per child (0-17 years old) for 2009-2013 was $7,569 resulting in an estimated savings of $31 per household;
- Average related ED visits for all individuals for 2009-2013 was $1,503 resulting in an estimated savings of $82 per household;
- After inflation, the average cost of all "other" medical costs was estimated to be $3,221 for 2014 resulting in an estimated cost savings of $137 per household;
- Combined, the total per household asthma-related cost saving was estimated to be $332;
- The household benefit portion of the total estimated savings was calculated by applying the estimate that 43% of the low-income population in MA have commercial (private) insurance (37%) or are uninsured (6%) and by then applying the estimate that of those meeting this criteria, 7% of medical costs associated with a chronic illness are spent OOP for a total of $9.99 per household served benefit;
- The remaining estimated cost savings were attributed as a societal benefit totaling $332.01 per household served; and
- PV was estimated using the OMB .44% discount rate over a 20-year measure lifetime.

Finally, our analysis indicates that 9.9 asthma-related adult hospitalizations, 4.2 asthma-related child hospitalizations and 54.6 ED visits are prevented annually per 1000 units weatherized.

It is logical to claim that weatherization can reduce environmental asthma triggers in the home and thereby reduce the use of urgent care facilities, and other direct medical expenses and indirect expenses associated with asthma. It was observed through the national Occupant Survey that reported incidences of seeking urgent healthcare through the ED and hospitals from asthma were reduced post-weatherization.

The following conservative considerations and approaches were taken in devising the valuation of the asthma NEI for this study:

- The survey question asked if head of household had asthma and did not ask if any other adult or child in the household had asthma. Asthma prevalence was estimated based on the head of household response only, which may be an underestimate of the percent of adults and children with asthma in WAP eligible homes. If the percentage is indeed higher, then additional savings would accrue.
- State-level asthma prevalence for the general population in Massachusetts is higher than the national rate (11.4% compared to 7.3%[44]) and therefore may have a higher percentage of household members reporting asthma than the estimate used for this analysis: 16.8% across WAP homes nationally.
- The survey question asked those who responded in the affirmative of still having asthma if they have ever been to the ED or been hospitalized for asthma in the past 12 months, but did not ask the number of times. The cost savings estimate was calculated using only one urgent care event and readmittance rate for each affirmative response.
- According to national healthcare utilization sources used for monetizing this benefit, nearly 1/3 of those who visit the ED for asthma are readmitted within six months, with re-admittance to the hospital for adults (27.3%) and children (22.9%) also occurring. Frequency rates were only applied by calculating a savings benefit based on *one* re-admittance event despite the possibility that these events may have occurred multiple times.

[44] Source: 2013 Behavioral Risk Factor Surveillance System (BRFSS) http://www.cdc.gov/asthma/brfss/2013/tableC1.htm

- The total benefit related to indirect costs (12%) was extracted from the cost savings attributed to better asthma control post-weatherization. This decision was made to eliminate the chance for “double-counting” of duplicate benefits accounted for elsewhere in the analysis (e.g., home productivity).
- The Black/African American population accounts for 19% of the WAP population served nationally. It is possible that in Massachusetts this minority and other communities of color make up a larger percentage of the population served through utility weatherization. Since communities of color tend to have higher asthma prevalence, poor asthma control, and more frequent use of urgent care, the cost savings from this benefit would be higher than the proposed estimates if higher rates are observed.
- OOP cost savings were applied to the percentage of the population in Massachusetts that are commercially insured or uninsured and does not consider OOP cost savings for Medicare or Medicaid recipients.

# 4.0 Reduced Thermal Stress on Occupants

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

- Elderly persons, pregnant women, and toddlers/infants
- Individuals with chronic medical conditions, mental disorders, or mobility impairments
- Any individual with inadequate food, clothing, or heating/cooling systems.

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

## 4.1 National WAP Evaluation—Summary of NEI Analysis

The baseline and follow up national Occupant Survey posed the following two questions to each respondent:

*In the past 12 months, has anyone in the household needed medical attention because your home was too cold?_____*

*In the past 12 months, has anyone in the household needed medical attention because your home was too hot?_____*

Survey results revealed the number of times that occupants were required to seek medical attention due to exposure to extreme temperatures inside their home was reduced post-weatherization.[45] Taking an average of differences (see Equation 1) yielded a decreased rate of seeking medical attention for cold- and heat-related illnesses of 1.4% and 1.1%, respectively (see Tables 4.1 and 4.2). One could argue that regardless of the incremental drop in rates of occurrence within this particular sample, these results have major policy implications.

*Equation 1. Change =*
*[(Pre-treatment – Post-treatment) + (Pre-treatment – Comparison group one year post-weatherization)] / 2*

[45] The project team considered to what extent the observed reductions in thermal stress could also be attributed to energy assistance subsidies funded Low-Income Home Energy Assistance Program (LIHEAP) (supported both by State level and the U.S. Department of Health and Human Services (DHHS) funds), especially first-time assistance. The incidence of thermal stress reported by households in the national occupant survey living in the cold climate zone was analyzed for households that did and did not report receiving LIHEAP. Nationally, about 50% of the survey respondents reported receiving LIHEAP assistance and 10% were first-year recipients at the time of the survey. The results suggest that households that reported receiving LIHEAP came into WAP somewhat "worse off" in that they originally suffered more incidences of thermal stress and also showed more improvement with respect to this metric post-weatherization. These results, however, do not support a strong conclusion about the extent to which this improvement is due to LIHEAP, their worse-off condition to begin with, and/or weatherization. Further, since not all weatherized homes receive LIHEAP, households typically receive energy assistance for multiple years, and LIHEAP payments are not timed to coincide with extreme weather events that are linked to thermal stress, we conclude that LIHEAP may potentially influence the observed reductions in thermal stress, but its contribution is uncertain and likely minimal.

The Occupant Survey did not provide a follow on question in order for the respondent to specify which *type* of medical attention (i.e., hospitalization, ED visit, physician office visit) was needed. Nor were questions asked regarding the death of a household member that may have occurred within the past 12 months due to thermal stress. Therefore, in order to accurately estimate total cost savings associated with the reduction of medical treatment and avoided deaths due to thermal stress, the following steps were taken:

- Secondary data sources were mined to establish the incidence rate, for the general U.S. population, of types of medical treatment used to treat these conditions.[46]
- A ratio based on the incidence of treatment type, from weighted averages over a 5 year period, was applied to the overall percent reduction in seeking medical treatment (Occupant Survey), for both cold and heat-related thermal stress.
- Average cost for each type of medical treatment were mined from the same secondary data source, and multiplied by the incidence of treatment type ratio.
- The percentage of death following hospitalization treatment for both cold and heat-related thermal stress, for general U.S. population, was mined from secondary data source.[47]
- Variables for "payer" (i.e., Medicare, Medicaid, Private/Other Insurance, Uninsured) were identified and isolated in order to group average yearly costs by payer. Average yearly out-of-pocket (OOP) costs were extracted from these costs.

The costs for treatment for cold and heat-related illnesses associated with thermal stress were retrieved from online databases provided by the Department of Health and Human Services (DHHS), sponsored by the Agency for Healthcare Research and Quality (AHRQ), based on the 2008 Medical Expenditure Panel Survey (MEPS)[48] as well as a collection of databases sponsored again by AHRQ referred to as the Healthcare Cost and Utilization Project (HCUP).[49]

Data related to incidence rates of treatment type and number of deaths following hospitalizations was mined from both MEPS and HCUP 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.

[46] It was assumed that the same national incidence rate for type of treatment could be applied to the WAP population. We believe this assumption results in a conservative estimate as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions. Therefore, one could argue the potential exists for the WAP population to require the higher-cost treatment (i.e., hospitalizations).
[47] Again, it was assumed, conservatively, that the same national rate of deaths following hospitalizations could be applied to the WAP population. We believe this is a conservative assumption as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions.
[48] Data generated from MEPS can be found on the following website: http://meps.ahrq.gov/mepsweb/
[49] These databases are derived from administrative data and contain encounter-level, clinical and nonclinical information including all-listed diagnoses and procedures, discharge status, patient demographics, and charges for all patients, regardless of payer (e.g., Medicare, Medicaid, private insurance, uninsured). HCUP is the largest collection of nationwide and state-specific longitudinal hospital care data in the United States and can be accessed at: http://www.ahrq.gov/research/index.html.

The inputs discussed above allowed for the annual cost savings of weatherization for the thermal stress NEI to be estimated. This total cost savings was further broken down and grouped as either a societal benefit or a household benefit.[50]

The NEI for reducing occurrences of medical treatment due to both cold and hot temperature exposure was monetized for the WAP evaluation using the following equations and inputs:

**Variables**

- Type of treatment:
  - *a = Hospitalization,*
  - *b = ED visit,*
  - *c = Physician office visit*
- *N (a, b, c)* = Total # of occurrences of medical treatment avoided, by treatment type
- Medical coverage type (i.e. payer):
  - $p_1$ = Medicare
  - $p_2$ = Medicaid
  - $p_3$ = Private/Other
  - $p_4$ = Uninsured (i.e., OOP)

**Equations**

Equation 2. *N (a, b, c) =*
[*(Number of WAP units completed in PY 2008) * (decreased rate of seeking medical care) * (% of type of medical treatment sought for cold and heat-related thermal stress (for a, b, and c)*]

Equation 3. *% of annual medical costs—(for $p_1$, $p_2$, $p_3$, $p_4$)—for WAP population (for a, b, and c) = [[(% of WAP population by medical coverage type) * (% of medical costs—by payer—for U.S. population (for a, b, and c)] / (% of U.S. population by medical coverage type)]]*

Equation 4. *Benefit (without avoided deaths) =*
*[(N (a, b, c) * % WAP medical costs (for $p_1$, $p_2$, $p_3$, $p_4$)) * Ave. cost for treatment (for a, b, and c)]*

Equation 5. *# of avoided deaths=*
*[(% of hospitalizations resulting in deaths (U.S. population) * (# of hospitalizations prevented by WAP in PY 2008)]*

Equation 6. *Total benefit (avoided deaths included) =*
*[# of avoided deaths * VSL]*

**Inputs**

- Reported decreased rate of seeking medical care (2008):
  Cold exposure, 1.4%; heat exposure, 1.1% (Occupant Survey)
- For treatment of cold-related illnesses (2008):
  Hospitalizations = 10.0%, ED visits = 39.9%, Physician office visits = 50.1%

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

- For treatment of heat-related illnesses (2008):
  Hospitalizations = 4.0%, ED visits = 84.5%, Physician office visits = 11.5%
- # of hospitalizations (general U.S. population, 2008): 3,410 (cold), 3,387 (hot)
- # of deaths following hospitalizations (general U.S. population, 2008): 122 (cold), 81 (hot)
- % of hospitalizations resulting in deaths (general U.S. population, 2008): 4% (cold), 2% (hot)
- # of hospitalizations prevented (WAP population, 2008): 113 (cold); 35 (hot)
- # of potential deaths avoided (WAP population, 2008): 4 (cold), 1 (hot)
- VSL - $7.5 M

## 4.2 MA LI SF NEI Study

Findings from the Occupant Survey specific to respondents residing in the cold climate zone of the U.S. (see Figure 2.1 in Section 2.0) were used to estimate the thermal stress NEI for this study. The descriptive statistics from this analysis are presented in Tables 4.1 and 4.2, along with national findings for comparison purposes.

**Table 4.1. Reduction in Medical Care Needs due to Cold-Related Thermal Stress**

| | Pre-Wx Treatment | Post-Wx Treatment | Post-Wx Comparison | Change |
|---|---|---|---|---|
| **National** | 3.2% | 1.5% | 2.1% | 1.4% |
| **Cold Climate Zone** | **4.1% (N=318)** | **2.6% (N=190)** | **1.8% (N=331)** | **1.9%** |

*** p <.001, ** p<.01, *p < .05

**Table 4.2. Reduction in Medical Care Needs due to Heat-Related Thermal Stress**

| | Pre-Wx Treatment | Post-Wx Treatment | Post-Wx Comparison | Change |
|---|---|---|---|---|
| **National** | 2.4% | 1.5% | 1.1% | 1.1% |
| **Cold Climate Zone** | **3.8% (N=318)** | **1.1% (N=190)** | **0.9%* (N=331)** | **2.8%** |

*** p <.001, ** p<.01, *p < .05

The following inputs and methodology used for the WAP evaluation were adjusted to produce an estimate of this benefit for the MA LI SF NEI study.[51]

- Rate of decreased medical care is based on findings from cold climate zone only: 1.9% (cold); 2.8% (hot) (see Table 4.1 and 4.2 above).
- National average medical costs from 2008 (used in WAP evaluation) were adjusted to reflect 2008 medical costs for the state of MA[52]; those costs were then price-inflated to reflect 2014 medical costs (see Tables 4.3 and 4.4).[53]
- Percent of medical costs paid, by payer, for each treatment type (a, b, and c)[54] (adjusted for WAP income-eligible population in 2008) was adjusted for the MA LI population[55] in 2014 (See Table A.1 and A.2 in Appendix A).

[51] See Table A.1 and A.2 in Appendix A for more detailed information related to inputs and calculations.
[52] More specifically, the Boston-Brockton-Nashua metropolitan statistical area (MSA).
[53] These adjustments were based using medical care price indices provided by the U.S. Bureau of Labor Statistics, http://data.bls.gov/timeseries/CUURA103SAM?data_tool=XGtable
[54] This cost and payer data was exported from MEPS and specific to ICD-9 primary diagnostic codes, "Effects of reduced temperature" (ICD-9-CM 991.0-991.9) and "Effects of heat and light" (ICD-9-CM 992.0-992.9). http://meps.ahrq.gov/mepsweb/

**Table 4.3. Adjusted Medical Costs for Treatment of Cold-Related Thermal Stress**

| Average Costs: Cold-Related Thermal Stress | | |
|---|---|---|
| **Type of Treatment** | **National 2008** | **MA 2014** |
| **Hospital Visit** | $9,455 | $15,052 |
| **Household Cost** | $776 | $906 |
| **Societal Cost** | $8,679 | $14,146 |
| **ED Visit** | $552 | $980 |
| **Household Cost** | $120 | $350 |
| **Societal Cost** | $432 | $630 |
| **Physician Visit** | $136 | $248 |
| **Household Cost** | $22 | $32 |
| **Societal Cost** | $114 | $216 |

**Table 4.4. Adjusted Medical Costs for Treatment of Heat-Related Thermal Stress**

| Average Cost: Heat-Related Thermal Stress | | |
|---|---|---|
| **Type of Treatment** | **National 2008** | **MA 2014** |
| **Hospital Visit** | $5,802 | $9,657 |
| **Household Cost** | $451 | $589 |
| **Societal Cost** | $5,351 | $9,068 |
| **ED Visit** | $624 | $980 |
| **Household Cost** | $139 | $350 |
| **Societal Cost** | $485 | $630 |
| **Physician Visit** | $136 | $248 |
| **Household Cost** | $22 | $32 |
| **Societal Cost** | $114 | $216 |

The following bullets document adjustments to inputs and refinements to methods related to estimating the benefits of avoided deaths from thermal stress for this study[56] (See Table 4.5):[57]

- % of hospitalizations resulting in deaths adjusted from national 2008 data to national 2013 data: 2.5% (cold); 1.28% (hot)[58]

[55] http://kff.org/

[56] Due to insufficient data for 2014, all data related to deaths were from 2013. All national and state-level data related to hospitalizations and deaths following hospitalizations were mined from HCUP.

[57] See Table A.3 and A.4 in Appendix A for more detailed information related to inputs and calculations for avoided deaths from thermal stress.

[58] This data was unavailable at MA state level as sample sizes were too low to be reported; therefore, assumptions were made that the same national rate of hospitalizations resulting in death could be applied to the MA region.

- A rate of reduction in thermal stress deaths due to weatherization was calculated (See Table 4.5): 0.004776% (cold); 0.001434% (hot)

*Equation 7.*

*Rate of reduction in thermal stress reduction (%) = [(decreased rate of seeking medical care due to weatherization (cold climate zone)) * (% of hospitalizations sought for cold and heat-related thermal stress (national rate) * (% of hospitalizations from thermal stress resulting in deaths (national rate)]*

- VSL adjusted from $7.5 M to $9.6M and avoided deaths applied as a household benefit rather than a societal benefit

**Table 4.5. Inputs—Estimating Avoided Deaths from Exposure to Extreme Thermal Conditions**

| | Cold-related | Heat-related |
|---|---|---|
| **Rate of decreased medical care from thermal stress due to weatherization (based on occupant survey results for cold climate zone)** | 1.9% | 2.8% |
| **% of hospitalizations resulting in deaths from thermal stress (national rate, 2013)** | 2.5% | 1.28% |
| **Rate of reduction in deaths due thermal stress attributable to weatherization (based on occupant survey results for cold climate zone)** | 0. 004772% | .001434% |
| **VSL** | $9.6M | $9.6M |
| **Household avoided death NEB$, per weatherized unit, per year** | **$458.54** | **$137.65** |

## 4.3 Findings

Tables 4.6 and 4.7 present estimates of the thermal stress NEIs specifically for low-income weatherization programs in MA state. These tables include both annual and PV benefits per weatherized unit, assuming persistence of measures for a twenty-year period. For cold-related medical conditions our analysis indicates that 0.05 deaths, 1.9 hospitalizations, 7.6 ED visits, and 9.5 physician office visits are prevented annually per 1000 units weatherized. For heat-related medical conditions our analysis also indicates that 0.01 deaths, 1.1 hospitalizations, 23.6 ED visits, and 3.2 physician office visits are prevented annually per 1000 units weatherized.

It should be noted that all thermal stress NEI values could be understated as it was assumed that extreme temperatures impact only one person per household (due to limitations of survey tool design) and results for any one year could be quite sensitive to extreme winter and summer weather events. Furthermore, estimates derived from existing data that include the general population is similarly conservative as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions.

**Table 4.6. Estimated Impact of Reduced Medical Treatment and Avoided Deaths Due to Exposure to Extreme Cold Temperatures[59]**

| | Annual Per Unit Benefit | Annual Per Unit Benefit W/O Avoided Death Benefit | PV Per Unit Benefit | PV per Unit Benefit W/O Avoided Death Benefit |
|---|---|---|---|---|
| **Households** | $463.21 | $4.67 | $8,849.71 | $89.30 |
| **Society** | $33.73 | $33.73 | $644.47 | $644.47 |
| **Total** | **$496.94** | **$38.40** | **$9,494.18** | **$733.77** |

**Table 4.7. Estimated Impact of Reduced Medical Treatment and Avoided Deaths Due to Exposure to Extreme Hot Temperatures**

| | Annual Per Unit Benefit | Annual Per Unit Benefit W/O Avoided Death Benefit | PV Per Unit Benefit | PV per Unit Benefit W/O Avoided Death Benefit |
|---|---|---|---|---|
| **Households** | $145.93 | $8.28 | $2,787.95 | $158.19 |
| **Society** | $27.00 | $27.00 | $515.86 | $515.86 |
| **Total** | **$172.93** | **$35.28** | **$3,303.81** | **$674.05** |

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

# 5.0 Fewer Missed Days of Work

Weatherization makes homes more comfortable, healthy, and safe. It is logical to presume that weatherization can lead to improvement in occupants' health. It is also logical to presume that improvements in occupants' health will allow employed occupants to miss fewer days of work due to illness or injury. Fewer missed days of work minimizes loss of pay, especially for employed respondents who do not have sick leave.[60] For those workers who do have sick leave, then a reduction of missed workdays would benefit their employers/society.

## 5.1 National WAP Evaluation—Summary of NEI Analysis

Numerous questions from the national Occupant Survey support the contention that occupants are healthier post-weatherization. Employed respondents[61] were directly asked how many days in the previous year they had missed work due to illness or injury of themselves and other family members both pre- and post-weatherization. Findings indicated fewer missed days of work (0.6 days) post-weatherization. Monetizing the estimated value of not missing a day of work was straightforward using published average hourly income of low-income workers and the percent of low-income workers without sick leave.[62] The complete equation is below.

*Benefit = (number of Wx Jobs completed in PY 2008) * (% of WAP households with an employed primary wage earner) * (reduction in missed days work) * (ave. hourly wage) * (8 hours/day)*

The household benefit was calculated by multiplying the product of the above equation by the percent of low-income workers without sick leave. The societal benefit is calculated by multiplying the previously described product by the percent of low-income workers who do have sick leave.

## 5.2 MA LI SF NEI Study

Answers to these survey questions from respondents living in the cold climate zone were used to estimate this benefit for the cold climate state of Massachusetts (see Table 5.1). The change in missed days at work attributable to weatherization is calculated using Equation 1 discussed in Section 1.2.2:

*Equation 1: Change = [(Pre-wx treatment - Post-wx treatment) + (Pre-wx treatment - Post-wx comparison)]/2*

**Table 5.1. Missed Days at Work: Survey Results**

| | Pre-Wx Treatment | Post-Wx Treatment | Post-Wx Comparison | Change |
|---|---|---|---|---|
| **National** | 7.7 (N=181) | 6.9 (N=103) | 7.3* (N=202) | 0.6 |
| **Cold Climate Zone** | **10.6 (N=92)** | **4.1 (N=60)** | **9.1** (N=89)** | **4.0** |

*** p <.001, ** p<.01, *p < .05

[60] Percent of low -income workers without sick leave: 80%. See: http://www.nationalpartnership.org/site/PageServer?pagename=psd_toolkit_quickfacts

[61] Percent of WAP households with an employed primary wage earner: 34%. The estimate may be under-valued because only one the head-of-household responded to this question.

[62] In 2013, the average hourly wage was $14.32 for a renter. See: http://nlihc.org/oor/2013

The methodology used for the WAP evaluation was modified in several manners to produce an estimate of this benefit for the MA LI SF NEI study.[63] The following bullet documents the adjustments:

- The average estimated hourly wage for a renter (as is assumed in the national methodology) was increased to reflect 2014 wages in Massachusetts: $17.17/hour (increased from $14.32/hour)

## 5.3 Findings

Table 5.2 below presents the estimates of this impact for the MA LI SF NEI study. The table includes the annual per weatherized unit and the PV of the benefit per unit, assuming a twenty-year life impact of weatherization on this benefit. The results in Table 5.2 can be considered conservative because only one worker per household was included in the benefit calculation.

**Table 5.2. Estimated Impact of Fewer Missed Days of Work**

| | Annual Per Unit Benefit | PV Per Unit Benefit |
|---|---|---|
| **Households** | $149.45 | $2,855.21 |
| **Society** | $37.36 | $713.80 |
| **Total** | **$186.81** | **$3,569.01** |

[63] See Table A.5 in Appendix A for more detailed information related to inputs and calculations for impacts of fewer missed days of work.

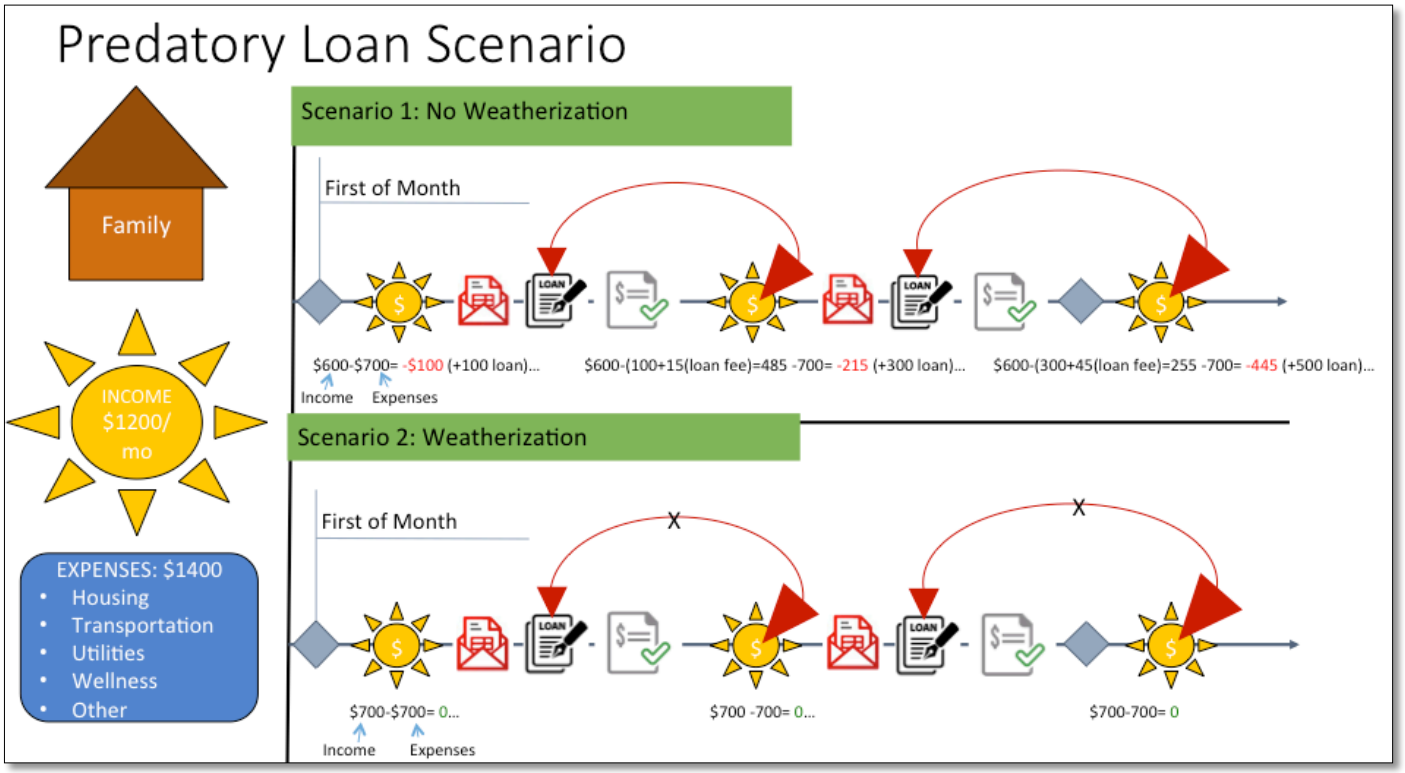
# 6.0 Reduced Use of Short-Term, High Interest Loans

It is assumed that weatherizing homes and the attendant energy cost savings, water cost savings, and other positive synergistic impacts on households' budgets (e.g., fewer missed days at work, less arrearages, disconnect and re-connection fees) produces a household budget situation where households less frequently find themselves financially tapped when utility and other bills are due. At times, households facing immediate financial stress will seek short-term, high interest loans, such as pay-day or title loans. This is a problem because households have to pay large interest fees that they cannot afford or in some cases, as shown in Figure 6.1, households can quickly see their budget stressors compounding.

This small increase in household income can reduce the need to resort to these high interest loans in order to fund necessary household expenditures, thereby eliminating, or at least reducing, the high-interest fees associated with these loans. Thus, this benefit is not derived from households spending energy cost savings to pay back a loan but rather simply produces a situation where a loan is not required to make ends meet in the first place. For example, assume that weatherization saves the household $400 per year in energy costs. The household can spend these savings in any way, including in ways that yield societal benefits (e.g., able to afford prescription medications which in turn may reduce their consumption of medical insurance). This extra money, combined with even more extra money as discussed above, may allow the household to forgo a pay-day loan to pay for recurring household expense (e.g., rent). If, for example, the interest fee on a $400 pay day loan is $50, then the household has $450 extra to spend, not just $400. The extra $50 in saved interest charges represents a true benefit to the household and does not double count or overlap with the $400 in saved energy costs spent on household expenditures.[64]

[64] It is recognized that this NEI may not be considered a benefit in the current TRC context, though it could be considered if a different cost test were used in the future. Further research may be warranted to examine important positive feedback (i.e., multiplier effects) that weatherization has on household budgets that produce benefits beyond the energy cost savings.

**Figure 6.1. Impacts of Predatory Loans on Household Budget**




## 6.1 National WAP Evaluation—Summary of NEI Analysis

From the national Occupant Survey, it was found that fewer households reported experiencing service disconnections, re-connection fees, running out of bulk fuel, and having to pay less than the amount owed on their utility bill. Survey respondents were also asked this question:

*In the past year, have you used any of the following to assist with paying your energy bill?*

a. *Payday loan*
b. *Tax Refund Anticipation Loan*
c. *Car Title Loan*
d. *Other type of short term, high-interest loan*
e. *Pawn shop*

There was an incremental improvement in households not having to resort to using short-term, high-interest loans to make ends meet, with the largest drop being seen in the use of pawn shops. Having more room in the household budget to pay any type of bill seems to have led respondents to make less use of these predatory loans; thereby, reducing the expense of exorbitant loan fees (see Table 6.1) (Pew 2012, Elliehausen 2009; Karger 2004). The national Occupant Survey did not ask households to estimate total annual loan amounts or annual amounts of interest paid by loan category. Background research was conducted to estimate the amounts presented in Table 6.1.

**Table 6.1. Estimated Average Magnitude of Annual Short-term, High-Interest Loans per Household[65]**

| | Amount per Loan | Payments on Interest |
|---|---|---|
| **Pay Day Loan** | $375 | $93.75 |
| **Tax Refund Anticipation Loan** | $500 | $125 |
| **Car Title Loan** | $400 | $100 |
| **Other types** | $350 | $87.50 |
| **Pawn Shop** | $150 | $37.50 |

The total program impact was calculated using this formula:

*Total Impact = (number of Wx Jobs completed in PY 2008) * (percent reduction in households using short-term, high-interest loans) * (reduction in interest payments/loan fees)*

The inputs used in this equation were:[66]

- Percent reduction in households using short-term, high-interest loans: 6.75% (average between all type of loans)
- Average Loan: $335 (Assumed, based on National Occupant Survey results that the typical household makes use of only one loan type per year and only takes out one short-term interest loan per year.)[67]
- Average Interest/Loan Fees: $88.75 (Also assumed that loan was paid back in one month with a 25% monthly interest rate.)

## 6.2 MA LI SF NEI Study

The change in loan use attributable to weatherization from respondents living in the cold climate zone of the U.S. is presented in Table 6.2.

**Table 6.2. Percent Respondents Reporting Household had Used at least One Short-term High Interest Loan in the Previous Year**

| | Pre-Wx Treatment | Post-Wx Treatment | Post-Wx Comparison | Change |
|---|---|---|---|---|
| **National** | 18.6% (N=660) | 12.0% (N=392) | 11.7%*** (N=797) | 6.75% |
| **Cold Climate Zone** | **17.5% (N=314)** | **9.2% (N=186)** | **12.9%** (N=327)** | **6.45%** |

*** p <.001, ** p<.01, *p < .05

The inputs used for the WAP evaluation were not revised to produce an estimate more tailored to the Massachusetts context.[68] There was insufficient data associated with typical loan amounts

[65] http://www.nclc.org/images/pdf/high_cost_small_loans/ral/report-ral-2011.pdf
http://www.myfoxdc.com/story/17988457/up-to-10-percent-of-virginia-households-use-high-cost-loans#axzz2W7hF0Noh
http://www.businessinsider.com/pawnshop-customers-statistics-2011-11?op=1
http://www.nber.org/papers/w17103.pdf

[66] See Table A.6 in Appendix A for more detailed information related to inputs and calculations for reduced use of short-term, high interest loans.

[67] Less than 5% of respondent households make use of more than one type of these loans per year.

and interest/loans fees at a state or even a regional level. However, data were updated to reflect loan and loan fee amounts for the 2014 timeframe, with the average interest/loan fee adjusted to $73.18. These adjustments resulted in a lower annual and PV per unit benefit than the national evaluation estimates.

## 6.3 Findings

Table 6.3 presents the estimates of this benefit for the MA LI SF NEI study. This table includes the annual per weatherized unit benefit and the PV of the benefit per unit, assuming a twenty-year life impact of weatherization on this benefit. These results can be considered conservative because the calculation assumes that households did or did not take out a loan (not multiple loans) only one time the past year.[69]

**Table 6.3. Estimated Impact of Reduced Use of Short-Term, High Interest Loans**

| | Annual Per Unit Benefit | PV Per Unit Benefit |
|---|---|---|
| **Households** | $4.72 | $90.18 |
| **Society** | $0 | $0 |
| **Total** | **$4.72** | **$90.18** |

[68] See Table A.6 in Appendix A for more detailed information related to inputs and calculations for reduced use of short-term, high interest loans.
[69] It is a conservative assumption that households that do make use of one of these loan types only do so once a year.

# 7.0 Increased Productivity at Home Due to Improved Sleep

It is assumed that weatherization improves living conditions in homes such that household members get more rest and sleep (e.g., temperatures are more comfortable in the winter and summer, the infiltration of outdoor noise is reduced). The literature supports the assumption that better rest and sleep improves work productivity at jobs outside of the home. It is further assumed from economic theory that productivity of work in the home is also improved. This means, for instance, that a weatherization recipient may be able to clean, cook, and do home maintenance chores more efficiency and effectively. His or her ability to take care of themselves and others in the home (e.g., children, persons of disability, elderly parents) may improve as well. Being more productive at home can benefit the household in many other ways as well. This benefit has a definite labor economic characteristic. While this benefit may be linked in a physical sense to improvements in home comfort and reduced intrusion of outdoor noise, this benefit is not a subjective estimate of how much recipients value feeling more comfortable in their homes or quieter homes. Therefore, this benefit does not double-count willingness-to-pay benefits associated with increased comfort and decreased noise pollution.

## 7.1 National WAP Evaluation—Summary of NEI Analysis

To explore this societal NEI, the question below was included in the national Occupant Survey. Averaging the change between the treatment group pre-weatherization and the comparison group surveyed in phase 1 and the treatment group pre- and post-weatherization yielded an estimated change of 5.5%.

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

This non-energy benefit was quantified as follows:

*Total Program Benefit = (number of Wx Jobs completed in PY 2008) * (percent decrease in at least one bad day of rest/sleep) * (cost per year per employee in productivity losses due to sleep problems/average national hourly wage rate) * wage rate for general housekeepers) * (average hours per week of housework/40 hours per work week)*

The inputs used in this equation are as follows:

- Percent decrease in respondents reporting at least one bad day of rest/sleep in the last thirty days: 5.0%
- Cost in lost productivity per year for employees with sleep problems[70]: $2,500
- Average national hourly wage rate[71]: $22.62
- Average hourly wage rate for general housekeeping[72]: $10.49
- Average hours per week on non-paid housework[73]: 21.5 hours

[70] http://www.businessinsider.com/workers-lack-of-sleep-costs-employers-millions-of-dollars-each-year-2011-1
[71] Bureau of Labor Statistics, August 2010; www.bls.gov
[72] http://www.bls.gov/oes/current/oes372012.htm
[73] (http://www.bls.gov/opub/mlr/2009/07/art3full.pdf)

## 7.2 MA LI SF NEI Study

As mentioned in the previous section, Occupant Survey respondents were asked how many days in the previous month they had bad rest and sleep. Answers to these survey questions from respondents living in the cold climate zone of the U.S. were used to estimate this benefit (see Table 7.1). The change in bad days of rest/sleep attributable to weatherization is calculated using Equation 1 provided in Section 2.1.2:

*Equation 1. [(Pre-Wx Treatment – Post-Wx Treatment) + (Pre-Wx Treatment – Post-Wx Comparison)] / 2*

**Table 7.1. Percent Decrease in Respondents Reporting at Least One Bad Day of Rest/Sleep in the Previous Month**

| | Pre-Wx Treatment | Post-Wx Treatment | Post-Wx Comparison | Change |
|---|---|---|---|---|
| **National** | 68% (N=650) | 65% (N=382) | 61% (N=788)** | 5.0% |
| **Cold Climate Zone** | **68% (N=315)** | **66% (N=181)** | **60%* (N=326)** | **5.0%** |

*** p <.001, ** p<.01, *p < .05

The other input used for the WAP evaluation that could be confidently adjusted to produce an estimate of this impact for the MA LI SF NEI study is bulleted below:[74]

- The average estimated hourly wage[75] for work in the home (as is assumed in the national methodology) was adjusted to reflect wages paid to Maids and Housekeeping Cleaners in 2014 in Massachusetts[76]: $12.71 (increased from $10.49/hour)

## 7.3 Findings

Table 7.2 presents the estimates of this impact for the MA LI SF NEI study. This table includes the annual per weatherized unit and PV of the impact per unit, assuming a twenty-year life impact of weatherization on this benefit. These results can be considered conservative because only one home worker per household was included in the benefit calculation.

**Table 7.2. Estimated Impact of Increased Home Productivity Due to Improved Sleep**

| | Annual Per Unit Benefit | PV Per Unit Benefit |
|---|---|---|
| **Households** | $37.75 | $721.26 |
| **Society** | $0 | $0 |
| **Total** | $37.75 | $721.26 |

[74] See Table A.7 in Appendix A for more detailed information related to inputs and calculations for increased home productivity.
[75] Estimated average hourly wage is unloaded (i.e., wage value does not reflect an organization's overhead or fringe costs).
[76] http://www.bls.gov/oes/current/oes372012.htm

# 8.0 Reduced Carbon Monoxide Poisoning

Carbon monoxide (CO) is a gaseous compound that results from inefficiently burning carbon-based fuels. These include many common household sources of heat and energy such as natural gas, oil, gasoline, kerosene, coal, wood, etc. Consequences of CO exposure can range from fatigue and nausea for low concentrations to severe poisoning and death for high concentrations. Symptoms of CO poisoning also vary due to length of exposure as well as general health and age of the victim. While proper safety, maintenance, and monitoring can prevent virtually all Unintended, Non-Fire Related (UNFR) CO poisonings, the socio-economic status of low-income households can make such precautions unaffordable. As such, these characteristics could put this population at significantly higher than average risk of UNFR CO poisoning.

## 8.1 National WAP Evaluation—Summary of NEI Analysis

Through WAP, combustion appliances – furnaces, water heaters, ovens and cooking ranges – are tested for gas leaks and CO emissions during audits and again during final inspections. All detected combustion safety issues are immediately addressed through appliance repairs or replacement. Carbon monoxide (CO) monitors are installed, or expired or defective CO monitors are replaced, in homes that use fossil fuels for heating. Literature provides documentation that the installation of CO monitors reduces incidents of UNFR CO poisonings, which, in turn, reduces ED visits, hospitalizations, and fatalities. This analysis focused on UNFR CO poisonings and on estimating the monetary value to households and society from installing CO monitors in weatherized homes.

As part of the national Occupant Survey, the treatment and comparison groups were asked if anyone in the household had been poisoned by breathing in carbon monoxide, and as a result had to seek medical attention.

Because of the small sample sizes relative to the incidence of CO poisonings and because the research methodologies were not designed to measure lives saved with respect to the installation of CO monitors, the methodology made heavy use of secondary data, along with data associated with the number of CO monitors installed by WAP in 2008.

The monetization of the CO benefit had the following components:

1. The number of ED, hospitalizations and deaths from CO poisoning nationally was estimated;

2. The number of ED, hospitalizations and deaths from CO poisoning potentially prevented by WAP was estimated;

3. Studies that estimated the preventative performance of CO monitors were evaluated;

4. Results from steps 1-4 were combined to estimate the number of ED visits, hospitalizations, and deaths from CO poisoning that could be prevented and attributable to WAP;

5. The monetary values of preventing the ED visits, hospitalizations, and deaths by household and society were estimated utilizing medical costs for the treatment of carbon monoxide poisoning[77]; and

6. Benefits were then divided into household benefits and societal benefits by applying primary payer information from HCUP and MEPS Household Component Event Files.[78] Cases paid by Medicare and Medicaid were considered societal benefits, while uninsured cases were household benefits. Cases whose primary payer was private/other were split between societal and household according to individual out-of-pocket (OOP) payment proportions from MEPS.

CO detectors vary in lifespan according to the model, but they generally remain effective for an average of five years (Rickert 2012; North Shore Fire Department 2011; BRK Brands, Inc. 2011). Therefore, it should be noted that for this NEI, a five-year time period was applied for this benefit rather than the fifteen-year time period applied to all other NEIs.

## 8.2 MA LI SF NEI Study

Respondents of the Occupant Survey had also been asked if their homes were heated using fossil fuels and, if so, whether they had a CO monitor and, if so, whether the monitor was functional. Answers to the survey questions from respondents living in the cold climate zone of the U.S. were used to estimate this benefit for the cold climate state of Massachusetts. The results are presented in Table 8.1.

[77] Mean medical costs were based on the ICD-9-CM code 986 “Toxic effect of carbon monoxide”. The hospitalization and ED costs were retrieved from an online database provided by the Department of Health and Human Services (DHHS) sponsored by the Agency for Healthcare Research and Quality (AHRQ). The data were collected through the Medical Expenditure Panel Survey (MEPS). (http://meps.ahrq.gov/mepsweb/)

[78] MEPS Household Component Event Files
http://meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp

**Table 8.1. Decision Matrix for Number of Total Replaceable CO Monitors**

| | | | | | |
|---|---|---|---|---|---|
| **Pre-Weatherization Treatment – National (N=665)** | | | | | |
| **Fossil Fuels as Heating Source?** | No 19.8% | | | | |
| | Yes → 80.2% | **Have CO Monitor? (N=523)** | No 43.8% | | |
| | | | Yes → 56.2% | **Functional CO Monitor? (N=287)** | No 7% |
| | | | | | Yes 93% |
| **Total Replaceable CO Monitors = 47.64%** | | | | | |
| | | | | | |
| **Pre-Weatherization Treatment – Cold Climate Region (N=318)** | | | | | |
| **Fossil Fuels as Heating Source?** | No 13.2% | | | | |
| | Yes → 86.8% | **Have CO Monitor? (N=272)** | No 37.9% | | |
| | | | Yes → 62.1% | **Functional CO Monitor? (N=164)** | No 8.5% |
| | | | | | Yes 91.5% |
| **Total Replaceable CO Monitors = 43.03%** | | | | | |

The methodology used for the WAP evaluation was modified in several manners to produce an estimate of this benefit for the MA LI SF NEI study. The following bullets document the adjustments:

- The percentage of weatherized homes using fossil fuels for heating was adjusted to reflect Massachusetts' percentages[79]: 86%
- The average size of households being weatherized was adjusted to reflect cold climate zone rates (Occupant Survey findings): 2.41[80]
- The percentage of homes below 200% of the federal poverty level (FPL) was adjusted to reflect Massachusetts' rates in 2014:[81] 27%[82]
- The average medical costs for ED visits and hospitalizations were adjusted in two steps: 1) national costs to Massachusetts prices for the year 2008, and then 2) the 2008 Massachusetts prices were adjusted to 2014 prices (see Table 8.2). These adjustments

[79] http://www.mass.gov/eea/images/doer/energy-dashboard/mass-energy-profile/heating-cooling-chart-2.png
[80] In contrast to the other NEIs estimated in this report, we were not limited by survey results to only focus on the respondent; therefore, we are assuming multiple occupants could be at risk in a single household.
[81] The threshold for qualifying as a low-income household in MA is higher than the 200% FPL (for a 4-person household, $63,704 in MA based on 60% of state median income vs. $48,600 as 200% of FPL, as shown at http://www.masslegalhelp.org/housing/poverty-guidelines ). As a result, these results likely understate the benefits to low-income households in MA.
[82] http://kff.org/other/state-indicator/population-up-to-200-fpl/

were based using medical care price indices provided by the U.S. Bureau of Labor Statistics.[83]

**Table 8.2. Adjusted Medical Costs for ED visits and Hospitalizations—2008 to 2014**

| | 2008 National | 2014 MA | 2008 National | 2014 MA |
|---|---|---|---|---|
| **Coverage Type** | **ED Visits** | **ED Visits** | **Hospitalizations** | **Hospitalizations** |
| **Private Other** | $1,337 | $2,136 | $5,929 | $9,475 |
| **Medicaid** | $842 | $1,345 | $10,796 | $17,251 |
| **Medicare** | $2,285 | $3,651 | $11,807 | $18,867 |
| **Uninsured** | $1,203 | $1,922 | $3,390 | $11,542 |

Due to time constraints, research on updated values of the preventative performance of CO monitors on UNFR CO poisonings was not conducted.

## 8.3 Findings

Table 8.3 below presents the estimates of this NEI for the MA LI SF NEI study. This table includes the annual impact per weatherized unit and the PV of the impact per unit, assuming a five-year life span of the typical CO monitor. Our analysis also indicates that 0.004 deaths, 0.07 hospitalizations, 0.47 ED visits, are prevented annually per 1000 units weatherized.

**Table 8.3. Estimated Impact of Reduced Carbon Monoxide Poisoning[84]**

| | Annual Per Unit Benefit (5-Year Life) | Annual Per Unit Benefit W/O Avoided Death Benefit | PV Per Unit Benefit (5 Years) | PV per Unit Benefit W/O Avoided Death Benefit |
|---|---|---|---|---|
| **Households** | $36.98 | $0.25 | $183.30 | $1.25 |
| **Society** | $1.87 | $1.87 | $9.28 | $9.28 |
| **Total** | **$38.85** | **$2.12** | **$192.58** | **$10.53** |

The NMR 2011 report does contain an NEI directly related to the reduction of CO poisoning. NMR's benefit was estimated from the installation of new furnaces, which, in turn reduces fire-related CO poisonings. Three[3] estimates only the Unintended and Non-Fire Related CO poisonings prevented by installing new and replacing non-working CO monitors. Therefore, the two methodologies measure two distinctively different NEIs related to weatherization and CO with respect to the causation of CO poisoning.

[83] http://data.bls.gov/timeseries/CUURA103SAM?data_tool=XGtable

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

# 9.0 Reduced Risk of Fire, and Fire-Related Property Damage

While numerous factors influence home fire occurrence and intensity, certain populations are particularly vulnerable. Persons who are elderly, persons of disability, those that live in sub-standard housing, or are of low socio-economic status have been linked with increases in fire frequency, rates of injury, and fire intensity (Istre, et al. 2001; Shai 2006). As such characteristics are proportionately more common among the population served by low-income weatherization, these applicants are exposed to higher than average home fire risks. These demographic indicators of fire risk often correspond to features of the home and occupant behavior associated with ignition and spread. For example, faulty wiring and unsafe methods of space heating are presumed more prevalent among residents of old homes and those who cannot afford to replace or repair dangerous heat sources. It is well known that weatherization reduces fires and fire damage through the replacement of furnaces, cleaning of dryer vents, and installation of smoke alarms. This section intends to quantify fire risk in homes that are eligible for low-income weatherization services, and to estimate the influence of weatherization on curbing potential for fire damages.

## 9.1 National WAP Evaluation—Summary of NEI Analysis

The national WAP evaluation Occupant Survey contained three questions that directly address home fires:

I*n the past 12 months how many times has the fire department been called to put out a fire in your home?*

*In the past 12 months did any fire start in your home as a result of using an alternate heating source, such as space heaters, electric blankets, your kitchen stove or oven, heating stove, furnace, or your fireplace?*

*In the past 12 months, how many individuals needed medical attention because of fire?*

While these questions address key aspects of fire, several factors restricted their ability to properly gauge fire risk among the WAP population. First, the Occupant Survey's sample size was too small to accurately describe fire frequency and consequence. The national WAP evaluation estimated the likelihood of fire among a population with household income similar to the WAP population. Though households in this sample face a decidedly larger likelihood of fire than the general population, these events occur relatively infrequently with less than four out of one thousand homes catching fire annually. Furthermore, the pre- and post-treatment survey method excluded extreme fire events. Major fire damage in these households could result in an occupant's death, relocation, or deferral of WAP services, which would prevent survey participation.

The WAP evaluation analysis also included estimates of costs related to injuries and deaths of firefighters. These estimates were applied as societal benefits.[85]

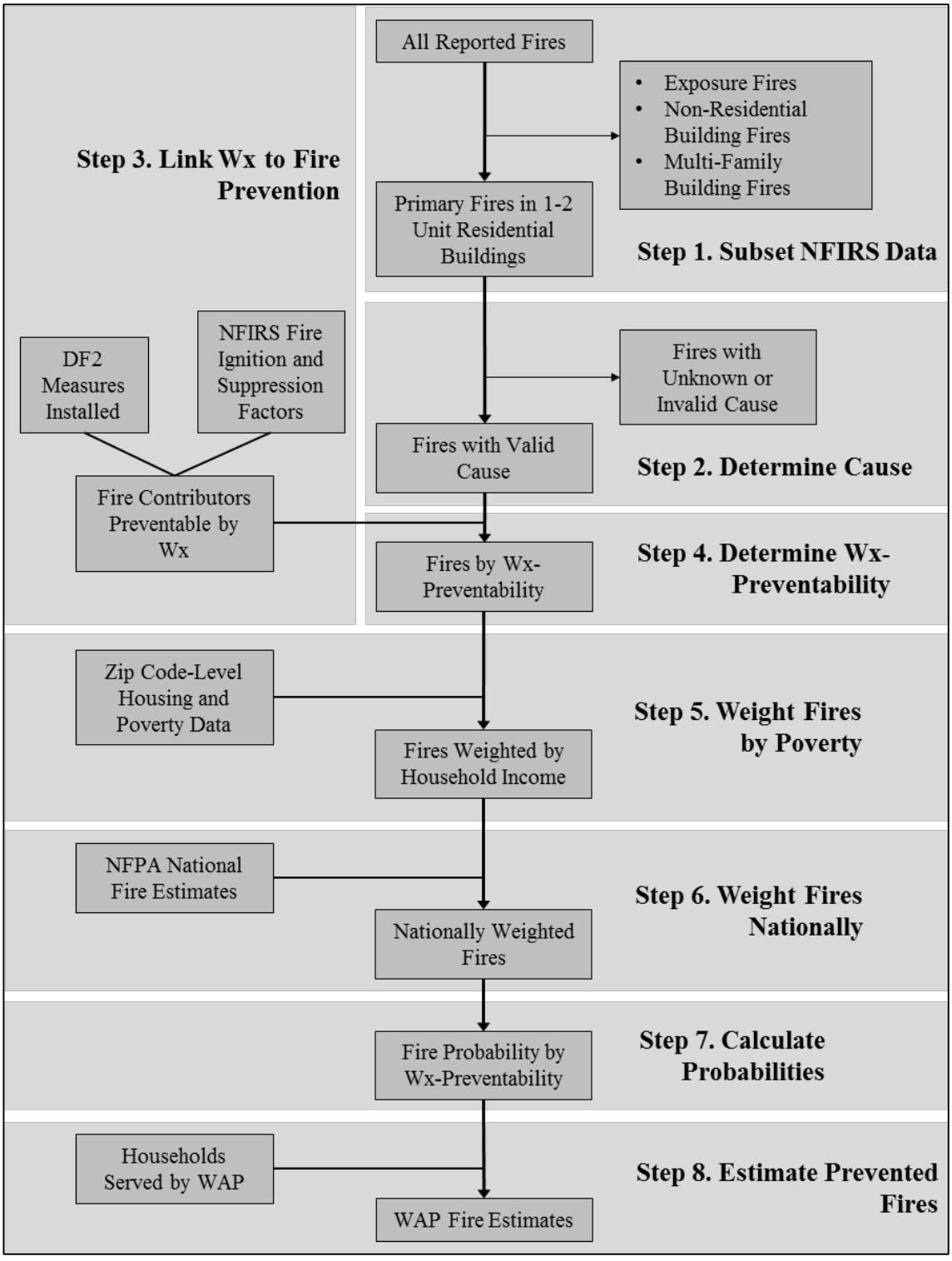
Fire risk and prevention among WAP households in single-family buildings followed these steps (Figure 9.1):

[85] Only firefighter injuries and deaths occurring at the fireground, i.e. the location of a fire incident, were included in the analysis. Valid fireground injury and death cases from the NFIRS Firefighter Casualty module were selected using variables on "where injury occurred" and "activity at time of injury" and merged with the larger dataset.

- National fire data are a subset of the National Fire Incident Reporting System (NFIRS) database that included primary fires in in one- and four-unit residential buildings.[86]
- General causes of these fires were determined and cases with unknown or invalid causes were removed from further consideration.
- Relevant fire incidents were identified by the presence of weatherization-preventable contributors to fire.
- Zip code-level housing and poverty data were matched with each fire to construct sample weights to estimate fire frequency among households under 200 percent of the poverty level.
- Fires and subsequent damages were weighted to estimate national totals.
- Probabilities of fire occurring in WAP homes were estimated using fire incidents and total homes among single-family households whose income was less than 200 percent of the poverty level.
- These probabilities were applied to the 80,352 single-family and mobile homes that received WAP services in 2008.

[86] Fire frequency and fire damage estimates came from the US Fire Administration's (USFA) National Fire Incident Reporting System (NFIRS). NFIRS 5.0 compiled and standardized fire incident data voluntarily reported from approximately 23,000 fire departments in the United States.

**Figure 9.1. Overview of WAP Fire Prevention Estimation Methodology**



## 9.2 MA LI SF NEI Study

Energy efficiency programs provided by PAs in Massachusetts install sets of measures comparable to the measures installed by WAP. Many such measures can reduce fire risk thereby reducing property damage in homes, and cases of occupant injury and/or death. From the WAP evaluation, 17 individual or sets of measures were investigated that have been assumed to reduce fire risk and damage (see Table 9.1), and are categorized as either igniters or suppressors. Measures shown to have the most impact on fire risk reduction are: central space heating systems; electrical repair; clothes dryer vent repair/replacement; insulation; and installation/replacement of smoke detectors.

**Table 9.1. Select Measures Proven to Reduce Fire Risk and Damage and Estimated Reduction in Risk (in %)**

| Individual Measures | Benefit % |
|---|---|
| **Igniters** | |
| **Electrical repair** | 16.55 |
| **Heating system** | 20.11 |
| **Cooling system** | 2.87 |
| **Clothes dryer vent repair/replacement** | 11.56 |
| **Refrigerator replacement** | 1.49 |
| **Water heater** | 4.73 |
| **Chimney repair** | 3.52 |
| **Fans repair/replacement** | 2.58 |
| **Lighting** | 2.84 |
| **Suppressors** | |
| **Smoke alarm installation/replacement** | 5.87 |
| **Windows, doors repair/replacement** | 2.41 |
| **Ventilation** | 3.68 |
| **Air sealing** | 2.39 |
| **Wall insulation** | 4.27 |
| **Roof, attic, ceiling insulation** | 12.20 |
| **Floor insulation** | 2.07 |
| **Gas** | 0.87 |

The methodology used to monetize this NEI for the WAP evaluation has been modified in several ways to be applicable for the MA LI SF NEI study. The adjustments to inputs utilized for the WAP model are as follows:

- Reduced fire risk in homes located in cold climate zone based on a range of the measures currently installed or under consideration (all those listed in Table 9.1).
- The average medical costs for ED visits and hospitalizations were adjusted in two steps: 1) national costs to Massachusetts prices for the year 2008, and then 2) the 2008 Massachusetts prices were adjusted to 2014 prices (see Table 9.2). These adjustments were based using medical care price indices provided by the U.S. Bureau of Labor Statistics.[87]

[87] http://data.bls.gov/timeseries/CUURA103SAM?data_tool=XGtable

**Table 9.2. Adjusted Medical Costs for Fire-Related Injuries—2008 to 2014**

| 2008 | Burn Center | Other Hospital | Emergency Department | Doctor's Office/Clinic |
|---|---|---|---|---|
| **Burns** | $26,210 | $14,227 | $722 | $250 |
| **Inhalation** | $39,592 | $8,310 | $459 | $353 |
| **Burn + Inhalation** | $72,671 | $22,994 | $1,433 | 0 |
| **Trauma** | $26,813 | $26,813 | $956 | $741 |
| **Other** | $6,050 | $6,050 | $548 | $336 |
| | | | | |
| **2014** | **Burn Center** | **Other Hospital** | **Emergency Department** | **Doctor's Office/Clinic** |
| **Burns** | $41,674 | $22,621 | $1,148 | $398 |
| **Inhalation** | $62,951 | $13,213 | $730 | $561 |
| **Burn + Inhalation** | $115,547 | $36,560 | $2,278 | 0 |
| **Trauma** | $42,633 | $42,633 | $1,520 | $1,178 |
| **Other** | $9,620 | $9,620 | $871 | $534 |

## 9.3 Findings

Table 9.3 below presents the estimates of this NEI specifically for low-income weatherization programs in Massachusetts. This table includes benefits both per weatherized unit annually and the PV per unit, assuming persistence of measures for a twenty-year period. Our analysis also indicates that: 0.0087 deaths, 0.013 hospitalizations, 0.4 ED visits, and 0.25 physician office visits, are prevented annually per 1000 units weatherized.

**Table 9.3. Estimated Benefit for Reduced Home Fire Occurrences[88]**

| | Annual Per Unit Benefit | Annual Per Unit Benefit W/O Avoided Death Benefit | PV Per Unit Benefit | PV per Unit Benefit W/O Avoided Death Benefit |
|---|---|---|---|---|
| **Households** | $93.84 | $9.77 | $1,792.84 | $186.68 |
| **Society*** | $17.87 | $17.60 | $341.39 | $336.28 |
| **Total** | **$111.71** | **$27.37** | **$2,134.23** | **$522.95** |

*Note: The avoided injuries and deaths to firefighters are categorized as a societal benefit.

The results in Table 9.3 can be considered conservative because:

- The probability of a fire post-weatherization is assumed to be the average probability of a home fire occurrence, not a lower probability.
- The probabilities of secondary fires were not considered.

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

## 9.4 Discussion

There is some overlap in the methodologies utilized by Three[3] for the MA NEI study and by NMR, but the efforts were not duplicative. The differences are as follows:

- The NMR estimate is based on preventing fires by replacing furnaces only, whereas the Three[3] estimate is based on preventing fires by the full range of weatherization measures.
- All causes of residential fires were mapped to all commonly installed weatherization measures, including furnace replacement (Three[3]).
- The methodology encompassed national weatherization measure installation rates and also adjusted for poverty levels by zip code (Three[3]).
- As with the other health- and safety-related NEIs discussed in previous sections, the medical cost estimates were broken down into types of coverage in order to bucket benefits as societal and household (Three[3]).

# 10.0 NMR's Recommendations

In 2011, the NMR Group conducted an evaluation study of non-energy impacts (NEIs) attributable to the Massachusetts (MA) Program Administrators' (PAs') residential and low-income programs that examined a number of health and safety-related benefits to low-income residents. The study included several individual health NEIs that NMR was not able to quantify due to insufficient data, such as reduced asthma, thermal stress and missed days from work (see Appendix A.6 and A.7 for the analysis and discussion).[89] In 2015, an evaluation of the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) was completed that included the assessment and monetization of twelve health and household-related impacts attributable to the weatherization of low-income homes, at a national level.[90,91]

The PAs tasked NMR to review the methodology utilized for the national WAP evaluation, as well as the findings from Three[3]'s MA LI SF NEI study presented in this report. The purpose of this task was to determine the extent to which the NEIs quantified in this WAP-based evaluation overlap with, augment, or supersede the health- and safety-related NEIs previously examined and/or currently claimed by the PAs, and to develop recommendations for integrating the results. At the time of the 2011 NEI report, NMR had noted that several health and safety NEIs, such as heat stress and cold exposure, were being examined by the WAP evaluation and recommended deriving values from the WAP evaluation when it became publicly available.

## 10.1 Reduced Asthma

The 2011 NMR report estimated an annual overall health NEI for low-income program participants of $19 per low-income participant who installed shell and weatherization measures or heating and cooling equipment based on a survey of program participants. The survey estimated health benefits as reductions in cases or symptoms of the cold, flu, or other illnesses (such as asthma) using the relative valuation method.[92]

NMR recommends that the PAs replace the single health NEI they currently claim with the reduced asthma NEI as well as other health-related NEIs included in this report: reduced thermal stress (see Section 4.0) and fewer missed days of work (see Section 5.0).

There is an extensive literature supporting the positive health impacts of energy efficiency programs through improved home environments (see Section 2.0 of this report, as well as section 5.16 of the 2011 NMR and Tonn et al., 2014, for reviews of the literature). While the NMR study quantified a general health benefit in the form of reductions in cases or symptoms of the cold, flu, or other chronic illnesses such as asthma, the same study found additional, limited, evidence of potential reductions in incidents of seeking medical care for asthma and thermal stress as well as

[89] NMR. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for Massachusetts Program Administrators. (See: http://ma-eeac.org/wordpress/wp-content/uploads/Special-and-Cross-Sector-Studies-Area-Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-Final-Report.pdf )

[90] A complete report presenting findings from this component of the WAP evaluation was published in 2014 and can be found at www.threecubed.org.

[91] A complete description of the methodology is found in: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.

[92] The survey asked respondents if they or anyone in their household experienced a change in the frequency or intensity of colds, flus, and other illnesses, such as asthma or other chronic health conditions, and if so, to quantify the value of that change relative to the estimated energy bill savings attributed to the energy efficiency improvements.

reductions in sick days (see Appendix A.6 and A.7 of the 2011 NMR report). However, because of the extremely small number of respondents reporting *program induced* changes in health, and, in the case of asthma, confounding results, NMR did not recommend estimating NEI values for these additional health benefits. For each health impact, the NMR study found reductions in seeking medical treatment or in the number of sick days among the total low-income study sample, but extremely small numbers of respondents attributed the change to the program.[93]

The WAP study and Three[3]'s MA LI SF NEI study were better able to detect and quantify these same health impacts because of larger sample sizes and because of the study design that included a pre- and post-weatherization comparison of WAP participants as well as a comparison group of WAP participants that did not rely on respondents assessing the causes of any health impacts identified by the respondent.

There is evidence from the MA LI SF NEI study of reduced urgent care (ED) visits and hospitalizations as well as decreased occurrence of high-cost asthma patients. While not all of the statistical analyses of the changes are statistically significant, the findings consistently find a positive effect from the weatherization and provide evidence for program effects (see Table 3.1-3.3). The evidence from MA LI SF NEI study, the literature (see Section 2.0 as well as NMR, 2011 and Tonn et al., 2014, for reviews of the literature), the NMR relative valuation survey (for general health impacts), and the limited evidence of reduced asthma medical visits from the low-income study population from the NMR study provides evidence of these health impacts.

The NEI monetization method for asthma employed in the MA LI SF NEI study is logical and comprehensive. The sources for medical cost data (Healthcare Cost and Utilization Project (HCUP) and the 2008 Medical Expenditure Panel Survey (MEPS)[94]) and Massachusetts-specific adjustments (the 2014 Costs Trends Report produced by the Health Policy Commission (HPC) and the Center for Health Information and Analysis (CHIA)) are robust and reliable. After removing the portion of the asthma NEI related to indirect costs to avoid double counting of total benefits, NMR believes the asthma NEI estimate presented in this report is the most accurate asthma NEI value available to the PAs at this time. NMR recommends supplanting the currently used overall health NEI estimate of $19 derived from the 2011 NMR study with the total asthma NEI value of $9.99 per household[95] as well as the other health-related NEIs included in this report: reduced thermal stress (10.2) and fewer missed days from work (10.3).

## 10.2 Reduced Thermal Stress on Occupants

There is evidence from the MA LI SF NEI study for reductions in both heat and cold-related thermal stress, though the evidence for reduced heat-related stress is stronger than the evidence for reductions in cold-related stress. The MA LI SF NEI study found reduced occurrences of both heat- and cold-related thermal stress post-weatherization for both the treatment and the comparison group, though only the difference between the pre and post comparison group for heat-related stress was statistically significant (see Section 4.0). Overall, the evidence from the MA LI SF NEI study, the literature (Section 5.16 of the 2011 NMR report), the NMR relative valuation survey (for general health impacts) and the limited evidence of reduced thermal stress

[93] These other potential health effects are reported in Appendix A.7 of the 2011 NMR report (NMR. 2011. Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. Prepared for Massachusetts Program Administrators)
[94] See Section 4.1 for more detailed information on these sources as provided by Three[3].
[95] As noted earlier in section 10.1, NMR recommends that the PAs replace the single health NEI they currently claim with the reduced asthma NEI as well as other health-related NEIs included in this report: reduced thermal stress (see Section 4.0) and fewer missed days of work (see Section 5.0).

in the total low-income study population from the NMR study (Appendix A.7 in the 2011 NMR report) provides evidence of these health impacts.

The NEI monetization method for heat- and cold-related thermal stress employed in the MA LI SF NEI study is logical and comprehensive. The sources for medical cost data (HCUP and MEPS) and Massachusetts-specific adjustments (U.S. Bureau of Labor Statistics and Kaiser Family Foundation) are reliable. NMR believes the heat- and cold-related thermal stress NEI values presented in this report are the most accurate values available to the PAs at this time. NMR recommends supplanting the currently used estimates of $19 of the health NEI derived from the 2011 NMR study with the cold- and heat-related thermal stress NEI values presented in this report ($463.21 and $145.93, respectively). The substantial increase in the thermal stress NEI is largely attributable to the avoided deaths by reducing the chance of an individual being subjected to dangerously cold or hot temperatures (See Section 4.0 for an overview of the risks of thermal stress).

The risks of thermal stress, including heat and cold-related mortality, are very real and substantial. A recent National Health Statistics Report estimated 2,000 weather related deaths per year in the U.S. from 2006 to 2010 (during the MA LI SF NEI study period) (Barko et al. 2014), with about 31% of these deaths attributed to exposure to heat-related causes and 63% attributed to exposure to excessive cold.The report includes estimates by region, estimating 307 heat and cold related deaths per year in the northeast region. Assuming the deaths are roughly proportionate to the population in each state, there are an estimated 36 cold- and heat-related deaths per year in Massachusetts, 29 of which were cold-related and eight of which are heat-related (See Table 10.1). While not all of these deaths are preventable by weatherization, statistics show that there are enough cold- and heat-related deaths in MA that can be prevented through home weatherization (as shown in Table E.3, a total of about 0.06 lives saved annually per 1,000 units weatherized).

**Table 10.1. Estimated Heat and Cold-related Deaths per Year in Northeast States, 2006 to 2010**

| State | Population (2010) | Percent of Northeast Region | # of Cold-related Deaths per Year | # of Heat-related Deaths per Year |
|---|---|---|---|---|
| **Massachusetts** | 6,547,629 | 12% | 29 | 8 |
| **Connecticut** | 3,574,097 | 6% | 16 | 4 |
| **Maine** | 1,328,361 | 2% | 6 | 2 |
| **New Hampshire** | 1,316,470 | 2% | 6 | 2 |
| **New Jersey** | 8,791,894 | 16% | 38 | 10 |
| **New York** | 19,378,102 | 35% | 85 | 23 |
| **Pennsylvania** | 12,702,379 | 23% | 56 | 15 |
| **Rhode Island** | 1,052,567 | 2% | 5 | 1 |
| **Vermont** | 625,741 | 1% | 3 | 1 |
| **Northeast Region** | 55,317,240 | 100% | 242 | 65 |

## 10.3 Fewer Missed Days of Work

There is evidence from the MA LI SF NEI study of a decrease in the number of missed days from work post-weatherization, for both the treatment and comparison groups, and the difference between the pre-treatment and post-comparison group was statistically significant (see Section 5.0). Overall, the evidence from the MA LI SF NEI study, the literature, and the limited evidence of reduced sick days in the total low-income study population from the NMR study (see Appendix A.6 of the 2011 NMR study) provides evidence of this health impact.

The NEI monetization method for missed days of work due to illness employed in the MA LI SF NEI study is logical and incorporates Massachusetts-specific hourly wage data. NMR believes the NEI value for missed days of work presented in this report is the most accurate measurement of health benefits associated with missed days of work available to the PAs at this time, and recommends supplanting the currently used health related NEI value estimate of $19 derived from the 2011 NMR study with the missed days of work due to illness NEI value of $149.45 presented in this report. The substantial increase in the NEI is attributable to the MA LI SF NEI study being able to estimate the number of missed days from work (for health-related reasons) and in turn to estimate lost wages whereas the 2011 NMR study relied on a single, self-reported estimate of health impacts.

## 10.4 Reduced Use of Short-Term, High Interest Loans

The 2011 NMR report examined a number of NEIs that are derived from customer bill savings and did not recommend including any NEIs that are derived from participant bill savings because it could amount to double counting of benefits. Participant bill savings partially overlap with avoided costs accounted for in the Avoided Energy Supply Costs (AESC) in New England (Hornby et al., 2011) and included in the TRC calculations (Hornby et al. 2011). While bill savings and avoided costs partially overlap, they typically differ in part because bill savings are based on average retail savings to participants while avoided costs are based on marginal energy supply costs that are avoided because of the PAs' energy efficiency programs. Theoretically, a participant NEI of bill savings, based on the difference between the avoided energy and capacity costs and participant energy bill savings, could be added to the TRC. However, according to traditional TRC calculation methods,[96] including participant bill savings as a benefit would require including a similar cost in the form of lost PA revenues, thus negating the bill savings benefit. Therefore, there is no additional NEI of participant bill savings

Because the benefit of *reduced use of short-term, high interest loans* is also derived from customer bill savings, NMR does not recommend counting this NEI.

It is also important to note that weatherizing homes reduces energy costs and therefore has positive effects on the household budgets of participating households. This can result in a number of benefits, including but not limited to reduced use of short-term, high interest loans, reduced incidence of service terminations and the costs associated with service termination and reconnection, increased spending on food or medicine, leading to improved health, and reduced need to move or forced mobility. It is possible that the benefits derived from the bill savings have a higher marginal impact on low-income households than the corresponding cost in the form of lost PA revenues. In other words, the benefits derived from bill savings may have a multiplier effect, resulting in more benefits than the associated costs. The PAs could consider further examination of the potential multiplier effect to determine if the benefits accruing to low-income households from bill savings are larger than the corresponding cost in the form of lost PA revenues.

## 10.5 Increased Productivity at Home Due to Improved Sleep

The 2011 NMR report found that participants in energy efficiency programs that include HVAC components and weatherization measures commonly experience greater comfort due to fewer drafts and more even temperatures throughout the home. The literature provides strong evidence that participants experience increased thermal comfort as a result of programs that affect the heating and cooling of the home, and that they consider these increased comfort levels to be a very important program benefit, both in general terms and in relation to other perception-based NEIs.

Based on the surveys of program participants, NMR recommended an annual value of $101 for low-income participants who installed shell and weatherization measures or heating and cooling equipment.

The MA LI SF NEI study theorized that the NEI of *increased productivity at home* is attributable to making the weatherized homes more comfortable and conducive to better sleep and therefore

[96] Though it should be noted that this NEI might be able to be counted if a different cost test were used in the future.

likely overlaps with the NEI of improved thermal comfort currently claimed by the PAs.[97] Because of the potential overlap, NMR recommends counting half the NEI value for *increased productivity at home* (to an adjusted value of $18.88).

## 10.6 Reduced Carbon Monoxide Poisoning

The 2011 NMR study quantified several safety-related NEIs attributable to replacing heating systems, including an annual NEI of $6.38 due to avoided deaths attributable to carbon monoxide (CO) poisonings. NMR used the assumptions from the 1993 evaluation of the WAP (Brown et al., 1993), assuming that 100% of CO poisonings attributable to heating systems are avoided.

The NEI monetization method for reduced CO poisonings attributable to CO monitors installed by the program is logical and comprehensive, even accounting for the efficacy of CO monitors in preventing injury and death. The sources for medical cost data (HCUP and MEPS) and Massachusetts-specific data (MA DOER) are reliable. The NEI value accounts for both injury and death resulting from CO poisoning.

The MA LI SF NEI study estimated an NEI of reduced CO poisoning attributable to the CO monitors installed by the program. At the time of the NMR study, the PAs' programs did not install CO monitors, so the benefit currently claimed by the PAs—a portion of the Improved Safety NEI that also accounts for fire-related impacts— is limited to reductions in deaths attributable to CO poisonings avoided by replacing heating systems. NMR believes that Three[3]'s NEI estimate for avoided CO poisoning overlaps with the portion of the Improved Safety NEI that accounts for avoided CO deaths. Although CO monitors and heating systems are mutually exclusive measures, their combined impacts on reduced CO poisonings are not additive. Presumably, the installed CO monitors would prevent nearly all, if not all, CO poisonings that are prevented by a replaced heating system, while also preventing additional CO poisonings attributed to other causes, such as stoves, dryers, heaters and other equipment.

NMR recommends replacing the portion of the Improved Safety NEI attributable to avoided carbon monoxide poisonings ($6.38) derived from the 2011 NMR study with the NEI value from reduced CO poisoning presented by Three[3] in this report ($36.98 annually over the 5-year life of the CO monitor, or one-time 5-year PV of $183.30).

## 10.7 Reduced Risk of Fire, and Fire-Related Property Damage

The 2011 NMR study quantified several fire safety-related NEIs attributable to replacing heating systems: avoided fire deaths, avoided fire-related injuries, and avoided fire-related property damage.

Reduced incidence of fire (and CO exposure) are commonly identified as safety-related benefits resulting from weatherization programs in the NEI literature. Faulty heating equipment is among the common causes of residential fires (Insurance Information Institute, 1990 as cited in Brown et al., 1993). Additionally, low-income households that cannot afford to pay their heating bills, or have been terminated from service due to nonpayment, have been known to resort to alternative sources of home heating, which are more likely to cause fires and CO poisoning. Similarly,

[97] The WAP study found evidence of overlap between comfort and sleep through their household survey, finding that warmer, less drafty homes were correlated with better sleep. In addition, the study found that bad sleep is positively correlated with bad physical health days, suggesting potential overlap between the WAP health NEIs and increased productivity (as increased productivity is monetized through reducing productivity losses due to sleep problems).

households that have had electric service shut off and resort to candles for lighting are at an elevated risk of experiencing a fire.

The annual NEI values in the 2011 report were estimated using data on the incidence and causes of residential fires and estimates of the avoided costs from fires, including loss of life ($37.40), personal injury ($0.03), and property loss ($1.24).

The MA LI SF NEI study estimated NEI values for the same set of benefits as those currently claimed by the PAs: avoided fire deaths, avoided fire-related injuries, avoided fire-related property damage. The MA LI SF NEI study adopted a more detailed and expanded methodology, including accounting for the impacts of all weatherization measures (rather than limiting to the impacts of heating systems), adjusting fire incidence rates for poverty levels by zip code, included estimates of injuries and deaths for both household and firefighters (societal benefit), and accounting for medical costs covered by insurance and medical costs borne by participants.

NMR recommends that the PAs consider replacing the fire safety-related NEIs they currently claim ($38.67) with 61.25% of the $93.84 in fire safety-related NEIs estimated in this report (i.e., $57.48). The MA LI SF NEI study included measures not currently installed by the PAs programs (e.g., chimney repair), and the 61.25% reflects the reduction in fire risk due specifically to measures installed by the PAs programs, including the safety inspection, replacement, and/or installation of smoke detectors.

## 10.8 Apportionment of NEI Values to Measures

To estimate NEIs at the measure level, the evaluation team estimated NEIs at the measure level by following the procedures used in the 2011 NMR study. With the exception of CO and Fire, the team assigned a portion of a given NEI value to relevant individual measure based on the average energy bill savings for which the measure was responsible in the 2011 NMR study. As a result, the health-related NEIs are apportioned as follows: air sealing (29.9%), duct sealing (0.7%), heating system (27.7%), insulation (25.1%), pipe wrap (5.5%), service to heating or cooling system (6.1%), programmable thermostat (4.8%) and window replacement (0.08%). The NEI for CO is based on CO monitor installation and therefore the entire value is applied to projects that include safety reviews and installation of CO monitors (see Table 10.2 on the following page for the apportionment of NEIs by measure as well as a comparison of the 2011 NMR and 2016 Three[3] values for each main NEI category). Finally, the analysis in this report is able to estimate the reduction in fire risk on a measure-by-measure basis (see Section 9.0 for more details).

## Table 10.2. Apportionment of Household NEI Values to Individual Measures

| | | NEI Category and Recommended Values ($ per unit) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Reduced asthma symptoms | Reduced cold-related thermal stress | Reduced heat-related thermal stress | Fewer missed days at work | Total Health Benefits | Increased home productivity | Total Thermal Comfort (1) | Reduced CO Poisoning | Reduced Home Fires | | Total Improved Safety | |
| | **2011 NMR Value** | | | | | **$19.00** | | **$101.00** | $6.38 (Annual) (3) | | $38.67 (3) | **$45.05** | |
| | **Recommended Value (Three[3] 2016)** | $9.99 | $463.21 | $145.93 | $149.45 | **$768.58** | $18.88 | **$119.88** | $183.30 (One-Time) | | $93.84 | **$183.30 One Time for CO Detectors + $57.48 Annual for Fire and Smoke Detectors** | |
| **Measure** | **Percent of Bill Savings used to Apportion Health and Thermal Comfort NEIs (2)** | Annual | Annual | Annual | Annual | **Annual** | Annual | **Annual** | One-Time | Estimated Risk Reduction (Three[3] 2016) | Annual | **Annual** | |
| Aerator | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | | $0.00 | **$0.00** | |
| Air sealing | 29.9% | $2.99 | $138.66 | $43.69 | $44.74 | **$230.08** | $5.65 | **$35.89** | | 2.39% | $2.24 | **$2.24** | |
| Appliance (refrigerators and freezers) | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | 1.49% | $1.40 | **$1.40** | |
| Door | 0.005% | $0.00 | $0.02 | $0.01 | $0.01 | **$0.04** | $0.00 | **$0.01** | | | $0.00 | **$0.00** | |
| Duct sealing | 0.7% | $0.07 | $3.12 | $0.98 | $1.01 | **$5.17** | $0.13 | **$0.81** | | | $0.00 | **$0.00** | |
| Heating system | 27.7% | $2.77 | $128.45 | $40.47 | $41.44 | **$213.13** | $5.23 | **$33.24** | | 20.11% | $18.87 | **$18.87** | |
| Hot water system | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | 4.73% | $4.44 | **$4.44** | |
| Insulation | 25.1% | $2.51 | $116.41 | $36.67 | $37.56 | **$193.15** | $4.74 | **$30.13** | | 18.54% | $17.40 | **$17.40** | |
| Lighting | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | 2.84% | $2.67 | **$2.67** | |
| Pipe wrap | 5.5% | $0.55 | $25.51 | $8.04 | $8.23 | **$42.34** | $1.04 | **$6.60** | | | $0.00 | **$0.00** | |
| Service to heating or cooling system | 6.1% | $0.61 | $28.33 | $8.93 | $9.14 | **$47.01** | $1.15 | **$7.33** | | 2.87% | $2.69 | **$2.69** | |
| Low flow showerhead | 0% | $0.00 | $0.00 | $0.00 | $0.00 | **$0.00** | $0.00 | **$0.00** | | | $0.00 | **$0.00** | |
| Programmable thermostat | 4.8% | $0.48 | $22.34 | $7.04 | $7.21 | **$37.07** | $0.91 | **$5.78** | | | $0.00 | **$0.00** | |
| Window | 0.08% | $0.01 | $0.36 | $0.11 | $0.12 | **$0.60** | $0.01 | **$0.09** | | 2.41% | $2.26 | **$2.26** | |
| **Total** | **100%** | $9.99 | $463.21 | $145.93 | $149.45 | **$768.58** | $18.88 | **$119.88** | | 55.38% | $51.97 | **$51.97** | **Annual for Fire** |
| | | | | | | | | | | | | | |
| Smoke Detector Inspection/Replacement/Installation (3) | N/A | | | | | | | | | 5.87% | $5.51 | **$5.51** | **Annual for Smoke Detectors** |
| | | | | | | | | | | 61.25% | **$57.48** | **$57.48** | **Annual for Fire + Smoke Detectors** |
| CO Detector Inspection/Replacement/Installation (3) | N/A | | | | | | | | $183.30 | | | **$183.30** | **One-Time for CO Detectors** |
| | | | | | | | | | | | | $36.98 | (Annual for CO Detectors, 5 yrs) |
| | | | | | | | | Other Measures to Which the Fire NEI can be Apportioned: | | | | | |
| | | | | | | | | | Electrical repair | 16.55% | $15.53 | | |
| | | | | | | | | | Clothes dryer vent repair/replacement | 11.56% | $10.85 | | |
| | | | | | | | | | Chimney repair | 3.52% | $3.30 | | |
| | | | | | | | | | Fans repair/replacement | 2.58% | $2.42 | | |
| | | | | | | | | | Ventilation | 3.68% | $3.45 | | |
| | | | | | | | | | Gas | 0.87% | $0.82 | | |

**Notes:**

(1) The revised value reflects NMR's 2011 estimate of $101 for Thermal Comfort plus half of Three[3]'s estimate for Increased Home Productivity (one-half of $37.75, or $18.88) to account for potential overlap.

(2) With the exception of Reduced CO Poisoning and Reduced Home Fires, the NEIs are apportioned based on the relative percentages of the average bill savings across those measures that are relevant and applicable to each NEI, as analyzed and computed in the 2011 NMR study.

(3) NMR's 2011 estimate for the Improved Safety NEI ($45.05) was based on an analysis of avoided deaths from fire-related CO poisonings ($6.38) and avoided fire deaths, injuries, and property damage (totaling $38.67) due to heating system replacement only. On the other hand, Three[3] is able to estimate the reduction in fire risk on a measure-by-measure basis, the results of which are reflected above. The revised NEI for CO Poisoning is based on CO monitor inspection/replacement/installation and therefore applies as a whole to each measure that involves the safety review, replacement and/or installation of CO monitors (i.e., is not apportioned among measures). The portion of the NEI for Reduced Home Fires attributable to smoke detectors ($5.51) is to be applied to each measure that involves the safety review, replacement and/or installation of smoke detectors.

Table 10.3 presents a comparison of the 2011 NMR and 2016 Three[3] values for each main NEI category as well as for two key measures, Weatherization and Heating System Retrofit/Replacement, on both an annual and 20-year PV basis.

**Table 10.3. Comparison of 2011 NMR and 2016 Three[3] NEI Values ($ per unit)**

| | Annual | | NPV (20 Yrs at 0.44%) | |
|---|---|---|---|---|
| | **NMR 2011** | **Three[3] 2016 (1)** | **NMR 2011** | **Three[3] 2016 (2)** |
| ***By NEI Category*** | | | | |
| Health Benefits | $19.00 | $768.58 | $363.00 | $14,683.78 |
| Thermal Comfort | $101.00 | $119.88 | $1,929.61 | $2,290.22 |
| Improved Safety | $45.05 | $94.46 | $860.68 | $1,281.40 |
| | | | | |
| ***By Key Measure*** | | | | |
| Weatherization, electric or gas (3) | $10.46 | $551.37 | $199.84 | $10,010.70 |
| Heating System Retrofit/Replacement, electric or gas (4) | $50.32 | $307.73 | $961.37 | $5,355.98 |

Notes:
(1) Three[3] 2016 annual NEI estimate for Improved Safety, Weatherization, and Heating System Retrofit includes annual estimate for CO monitors of $38.67 (5-year life).
(2) Three[3] 2016 NPV NEI estimate for Improved Safety, Weatherization, and Heating System Retrofit includes 5-yr (not 20-yr) NPV estimate for CO monitors of $183.30.
(3) Weatherization includes Health, Thermal Comfort, and Safety NEIs apportioned for air sealing, insulation, smoke detectors, and CO detectors.
(4) Heating System Retrofit/Replacement includes Health, Thermal Comfort, and Safety NEIs apportioned for heating system, smoke detectors, and CO detectors.

As shown in Table 10.3 the differences between the two sets of results are substantial. The reasons for these substantial differences are as follows:

- The NMR estimates were based on the survey (post-weatherization only) respondents' ability to recognize and report health effects monetized by their willingness to pay for improved health and comfort *relative to their energy bill savings*, whereas the Three[3] estimates are based on the Occupant Survey respondents' self-reported changes in health and household status (as measured from pre- to post-weatherization with a comparison group) and monetized using a more robust set of secondary data of national and state medical incidence (e.g., applicable types of medical treatment sought) and cost (e.g., by type of insurance coverage and treatment).
- The sample size of the Occupant Survey was substantially larger, increasing Three[3]'s ability to detect rare events such as the need for medical care and potential number of deaths due to thermal stress that could be avoided from weatherization.
- In the Three[3] analysis, the relatively few number of avoided deaths due to thermal stress, CO poisoning, and fire could therefore be monetized assuming a VSL of $9.6 million, which substantially increases the per unit value of the NEIs from the corresponding NMR estimate.

- NMR's survey questions referenced multiple health benefits collectively (colds, flus, asthma, and other chronic health conditions), whereas the Occupant Survey questions targeted each potential health benefit separately (asthma, thermal stress).
  NMR could estimate the benefit of improved safety from reduced CO poisoning and fires due to a single measure only (heating system retrofit/replacement), whereas Three[3] could estimate this benefit from a wider range of measures using a more robust set of secondary data of national and state CO and fire incidence.

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# Appendix

**Table A.1. Inputs and NEB Estimates for Thermal Stress-Cold**

| **Thermal Stress-Cold** | | | |
|---|---|---|---|
| **Self-reported decrease in medical care for thermal stress due to weatherization (WAP occupant survey - cold climate zone)** | **1.9%** | | |
| | **Office Visits** | **ED Visits** | **Hospitalizations** |
| **Insurance coverage ratio, specific to ICD-9 diagnostic codes, for payment of treatment type a, b, and c (*adjusted for MA LI population)** | | | |
| **Medicare** | 21% | 22% | 60% |
| **Medicaid** | 11% | 20% | 23% |
| **Private/Other** | 56% | 22% | 10% |
| **Uninsured** | 11% | 37% | 7% |
| **Percent of medical cost that is out-of-pocket (OOP) for Private/Other ONLY** | 10.34% | 8.87% | 3.26% |
| **Percent of medical care for thermal stress (national rate)** | 50.1% | 39.9% | 10.0% |
| **Reduction in medical care visits due to weatherization, per 1,000 weatherized units** | 9.5 | 7.6 | 1.9 |
| **Average Medicare cost (MA-adjusted, 2014)** | $185.12 | $1,069.59 | $13,700.80 |
| **Average Medicaid cost (MA-adjusted, 2014)** | $132.79 | $419.41 | $19,111.45 |
| **Average Private/Other cost (MA-adjusted, 2014)** | $321.68 | $1,577.17 | $16,249.09 |
| **Average Uninsured cost (MA-adjusted, 2014)** | $114.70 | $870.02 | $11,671.41 |
| **Household NEB$, per weatherized unit, per year (OOP costs)** | **$0.30** | **$2.65** | **$1.72** |
| **Societal NEB$, per weatherized unit, per year** | **$2.06** | **$4.78** | **$26.90** |

**Table A.2. Inputs and NEB Estimates for Thermal Stress-Hot**

| Thermal Stress- Hot | | | |
|---|---|---|---|
| **Self-reported decrease in medical care for thermal stress due to weatherization (WAP occupant survey - cold climate zone)** | **2.80%** | | |
| | **Office Visits** | **ED Visits** | **Hospitalizations** |
| **Insurance coverage ratio, specific to ICD-9 diagnostic codes, for payment of treatment type a, b, and c (*adjusted for MA LI population)** | | | |
| **Medicare** | 21.3% | 25.0% | 65.5% |
| **Medicaid** | 11.5% | 16.5% | 10.2% |
| **Private/Other** | 55.9% | 25.5% | 18.4% |
| **Uninsured** | 11.3% | 32.9% | 5.9% |
| **Percent of medical cost that is out-of-pocket (OOP) for Private/Other ONLY** | 10.3% | 8.9% | 3.3% |
| **Percent of medical care for thermal stress (national rate)** | 11.5% | 84.5% | 4.0% |
| **Reduction in medical care visits due to weatherization, per 1,000 weatherized units** | 3.2 | 23.6 | 1.1 |
| **Average Medicare cost (MA-adjusted, 2014)** | $185.00 | $1,070.00 | $9,169.00 |
| **Average Medicaid cost (MA-adjusted, 2014)** | $133.00 | $419.00 | $12,400.00 |
| **Average Private/Other cost (MA-adjusted, 2014)** | $322.00 | $1,577.00 | $7,515.00 |
| **Average Uninsured cost (MA-adjusted, 2014)** | $115.00 | $870.00 | $7,726.00 |
| **Household NEB$, per weatherized unit, per year (OOP costs)** | **$0.10** | **$7.62** | **$0.56** |
| **Societal NEB$, per weatherized unit, per year** | **$0.70** | **$16.65** | **$9.64** |

**Table A.3. Inputs and NEB Estimates for Avoided Deaths Related to Thermal Stress-Cold**

| Avoided Deaths: Thermal Stress-Cold | |
|---|---|
| Percent of hospitalizations from thermal stress resulting in death (national rate) | 2.511774% |
| Rate of reduction in thermal stress deaths due to weatherization | 0.00477237% |
| Reduction in thermal stress deaths per 1,000 weatherized units | 0.047723705 |
| VSL (USDOT) | 9,600,000 |
| Household avoided death NEB$, per weatherized unit, per year | **$458.54** |
| Total Household NEB$, per weatherized unit, per year | **$463.21** |
| Total Household NEB$ without avoided deaths, per weatherized unit, per year | **$4.67** |
| Total Societal NEB$, per weatherized unit, per year | **$33.73** |
| | |
| Discount rate (real) | 0.0044 |
| Life of benefit (years) | 20 |
| | |
| Household NEB$, PV per weatherized unit | **$8,849.71** |
| Household NEB$, PV per weatherized unit (without avoided deaths) | **$89.30** |
| Societal NEB$, PV per weatherized unit | **$644.47** |

**Table A.4. Inputs and NEB Estimates for Avoided Deaths Related to Thermal Stress-Hot**

| Avoided Deaths: Thermal Stress-Hot | |
|---|---|
| **Percent of hospitalizations from thermal stress resulting in death (national rate)** | 1.28% |
| **Rate of reduction in thermal stress deaths due to weatherization** | 0.00143382% |
| **Reduction in thermal stress deaths per 1,000 weatherized units** | 0.014338224 |
| **VSL (USDOT)** | $9,600,000 |
| **Household avoided death NEB$, per weatherized unit, per year** | **$137.65** |
| **Total Household NEB$, per weatherized unit, per year** | **$145.93** |
| **Total Household NEB$ without avoided deaths, per weatherized unit, per year** | **$8.28** |
| **Total Societal NEB$, per weatherized unit, per year** | **$27.00** |
| | |
| **Discount rate (real)** | 0.0044 |
| **Life of benefit (years)** | 20 |
| | |
| **Household NEB$, PV per weatherized unit** | **$2,787.95** |
| **Household NEB$, PV per weatherized unit (without avoided deaths)** | **$158.19** |
| **Societal NEB$, PV per weatherized unit** | **$515.86** |

**Table A.5. Inputs and NEB Estimates for Missed Days of Work**

| Missed Days of Work | |
|---|---|
| **Self-reported decrease in missed work days due to weatherization (WAP occupant survey - cold climate zone)** | 4 |
| **Percent of LI households with an employed primary wage earner** | 34.0% |
| **Average hourly wage (renter, MA-adjusted to 2014)** | $17.17 |
| **Work hours per day** | 8 |
| | **$186.81** |
| | |
| **Percent of LI workers without sick leave (national)** | 80.0% |
| **Total Household NEB$, per weatherized unit, per year** | **$149.45** |
| **Percent of LI workers with sick leave** | 20.0% |
| **Total Societal NEB$, per weatherized unit, per year** | **$37.36** |
| | |
| **Discount rate (real)** | 0.0044 |
| **Life of benefit (years)** | 20 |
| | |
| **Household NEB$, PV per weatherized unit** | **$2,855.21** |
| **Societal NEB$, PV per weatherized unit** | **$713.80** |
| **Total NEB$** | **$3,569.01** |

**Table A.6. Inputs and NEB Estimates for Short-Term, High Interest Loans**

| Short-Term, High Interest Loans | |
|---|---|
| **Self-reported decrease in use of short-term, high interest loans due to weatherization (WAP occupant survey - cold climate zone)** | 6.45% |
| **Average interest/loan fees (national, 2014-adjusted)** | $73.18 |
| **Total Household NEB$, per weatherized unit, per year** | **$4.72** |
| | |
| **Discount rate (real)** | 0.0044 |
| **Life of benefit (years)** | 20 |
| | |
| **Household NEB$, PV per weatherized unit** | **$90.18** |

**Table A.7. Inputs and NEB Estimates for Increased Productivity at Home Due to Improved Sleep**

| Increased Home Productivity | |
|---|---|
| Percent increase in respondents reporting no sleep problems in the last 30 days | 5.0% |
| Cost in lost productivity per year for employees with sleep problems | $2,500 |
| Average national hourly wage rate | $22.62 |
| Average hourly wage rate for general housekeeping (MA-adjusted, 2014) | $12.71 |
| Average hours per week on non-paid housework (BLS) | 21.5 |
| No. of hours per work week | **40** |
| **Total Household NEB$, per weatherized unit, per year** | **$37.75** |
| | |
| **Discount rate (real)** | 0.0044 |
| **Life of benefit (years)** | 20 |
| | |
| **Household NEB$, PV per weatherized unit** | **$721.26** |