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Health and Household-Related Benefits Attributable to the Weatherization Assistance Program

Bruce Tonn
Erin Rose
Beth Hawkins
Brian Conlon

September 2014

OAK RIDGE NATIONAL LABORATORY
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Environmental Sciences Division

HEALTH AND HOUSEHOLD-RELATED BENEFITS ATTRIBUTABLE TO THE WEATHERIZATION ASSISTANCE PROGRAM

Bruce Tonn
Erin Rose
Beth Hawkins
Brian Conlon*
Oak Ridge National Laboratory

***Higher Education Research Experiences Program
administered by
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Prepared by
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CONTENTS

Page

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

ACRONYMS AND ABBREVIATIONS

ACS	American Community Survey
AHRQ	Agency for Healthcare Research and Quality
AHS	American Housing Survey
ANOVA	Analysis of Variance
ARRA	American Recovery and Reinvestment Act
CATI	Computer-assisted Telephone Survey
CDC WONDER	Center for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CPSC	Consumer Product Safety Commission
CY	Calendar Year
DHHS	Department of Health and Human Services
DF2	WAP Housing Unit Information
DOE	Department of Energy
ED	Emergency Department
EI	Equipment Involved in Ignition
EPA	Environmental Protection Agency
EPA VSL	Environmental Protection Agency's Value of a Statistical Life
HCUP	Healthcare Cost and Utilization Project
HHD	Household
HHS	Health and Human Services
HVAC	Heating, Ventilation and Air Conditioning
IEQ	Indoor Environmental Quality
IPCC	Intergovernmental Panel on Climate Change
MCD	Multiple Cause of Death
MEPS	Medical Expenditure Panel Survey
MH	Mobile Home
NCHS	National Center for Health Statistics
NEBs	Non-energy Benefits
NEDS	Nationwide Emergency Department Sample
NEIs	Non-energy Impacts
NFIRS	National Fire Incident Reporting System
NFPA	National Fire Protection Association
NIH	National Institute of Health
NIS	Nationwide Inpatient Sample
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
PM	Particulate Matter
POCs	Persistent Organic Compounds
PV	Present Value
PY	Program Year
SES	Socioeconomic Status
SF	Suppression Factors
SVOCs	Semi-volatile Organic Compounds
3SLS	Three-Stage Least Squares
UNFR	Unintentional and Non-fire-related
USFA	US Fire Administration

VSCP	Vital Statistics Cooperative Program
WAP	Weatherization Assistance Program
WHO	World Health Organization

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EXECUTIVE SUMMARY

This report describes and monetizes numerous health and household related benefits attributable to the weatherization of low-income homes by the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP). WAP was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of the Program as currently stated in the Code of Federal Regulations (CFR) 10 CFR 440.1 is "to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden." (Code of Federal Regulations, 2011)

To achieve these goals, DOE provides grants to states, territories, tribes, and the government of Washington, DC; these grantees then fund local agencies (known as Subgrantees) to weatherize homes of low-income American householders. The Grantees and Subgrantees often leverage the DOE funding to obtain additional funding from states and utilities. Weatherization measures most frequently installed in homes are: air sealing; insulation (e.g., wall and attic); furnace repair and replacement; refrigerator replacement; and ventilation. The weatherization process itself is simply described: income-eligible households enter the Program; energy audits are performed on the homes; energy efficiency measures that meet a savings-to-ratio test, along with appropriate health and safety measures, are installed in the homes; and final inspections are conducted. Sometimes agencies need to defer weatherization if homes are in extremely poor physical condition or present health and safety risks to their personnel.

The beneficial impacts of low-income weatherization on human health can be broad and deep. Typically, non-energy benefits (NEBs), sometimes also referred to as non-energy impacts (NEIs), are bucketed into three general benefit categories: household, societal, and ratepayers. Examples of NEBs in each of these categories include: reduced carbon monoxide (CO) poisoning, reduced emissions of greenhouse gases, and reduced utility bill payment arrearages. The comprehensive non-energy benefit framework presented in this report greatly enhances the household component by recognizing that weatherization can provide many direct and second-order income benefits to households. Subsequent increases in income can be spent by households to yield societal and ratepayer benefits. Our framework extends the traditional household, societal, and ratepayer categories into these nine components:

- **Household**
    - Physical Changes to Home
    - Income Benefits
    - Household Expenditure Benefits
    - Health & Safety Benefits
    - Well-Being Benefits
- **Societal**
    - Economic Benefits
    - Environmental Benefits
    - Medical and Social Service Cost Benefits
- **Ratepayer**
    - Reduced Utility Costs

This report only focuses on the household expenditure benefits, household health and safety benefits, and the household well-being benefits.[1] Macro-economic, environmental and ratepayer benefits are monetized in separate reports as well as in a summary report entitled *Weatherization Works*.[2] A national occupant survey of random samples of weatherized (treatment) and a comparison group of households is the foundation for this research. The survey was conducted in two phases. The first phase was conducted just prior to the energy audits completed in the treatment group households (during calendar year (CY) 2011). The second phase was implemented post-weatherization, approximately 18 months later (during CY 2013).[3] Descriptive statistics generated from these surveys suggest the following post-weatherization benefits:

- Homes are more livable;
- The physical condition of homes is improved;
- These and other improvements lead to improved general health;
- Respondents experience fewer 'bad' physical and mental health days;
- Respondents and other household members suffer fewer persistent colds and headaches;
- There are fewer instances of doctor and emergency room visits, and hospitalizations;
- Households are better able to pay energy and medical bills;
- Households are better able to pay for food; and
- Households 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. Two approaches were taken to accomplish this task with respect to the health-related benefits. The first approach entailed directly asking clients whose homes were weatherized how their health-related expenses changed post-weatherization. Households who answered these questions reported saving just over $500 in out-of-pocket medical expenses post-weatherization and an additional $2,800 in additional health benefits from weatherization.

The second approach is more analytical and generally focused not on out-of-pocket expense changes reported by households, but on monetizing benefits that could be deemed to be societal (e.g.,, hospitalization costs paid by insurers and monetary benefits associated with avoided deaths). These eleven health-related non-energy benefits were treated in this analytical fashion:

- Reduced Carbon Monoxide Poisonings
- Reduced Home Fires
- Reduced Thermal Stress on Occupants
- Reduced Asthma-Related Medical Care 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

[1] It should be noted that this analysis focuses on short-term non-energy benefits - up to 10 years. Long-term non-energy impacts are worthy of future research.
[2] All reports will be published by Oak Ridge National Laboratory and can be located at http://weatherization.ornl.gov.
[3] A small number of households surveyed in the second round did not have weatherization completed due to their homes being deferred, n=122.

Table E.S.1 presents the present value (PV) of these monetized estimates per weatherized unit in the societal and household benefit categories. The PV of the benefits were estimated over a ten-year time horizon[4], using the discount rate published by the Office of Management and Budget for FY 2013. The estimates are presented in three tiers. Tier 1 estimates are based on observed monetizable outcomes attributable to weatherization (i.e., observed through the national occupant survey, pre- and post-weatherization with a control group) and highly reliable cost data. Tier 2 and 3 estimates all have sound methodologies underlying them but may lack direct observations of improved health or well-being (e.g.,, based on counts of carbon monoxide monitors installed rather than on survey reports of fewer CO poisoning post-weatherization) and/or require relatively more assumptions. Also, the PV benefits are presented with and without including the value of lives saved. To help gauge the magnitude of these benefits, the average weatherization cost per unit (includes energy and non-energy measures; excludes administrative costs) in PY 2008 for a site-built single family home was approximately $4000. The PV per unit of health-related benefits is estimated to be $14,148. The main contributors to this estimate are: avoided deaths from CO poisoning, fire, and thermal stress; avoided hospitalizations and emergency department (ED) visits related to these three areas as well as asthma-related symptoms; increased ability to afford prescriptions; and disposable income gains from fewer missed days at work.

Much additional research is needed in this general area. For example, definitive studies are needed that directly establish relationships between the installation of individual and combinations of weatherization measures and reductions in fire risk and asthma-related symptoms. Studies that track in more detail the health of household members (including children) and health-related expenditures and costs of households (e.g., Medicaid, Medicare, and private health insurance) pre- and post-weatherization are needed. More data are needed on how weatherization may reduce exposure to outdoor air pollutants and noise. The medical community needs to be engaged to ensure that research designs and results are acceptable and valuable.

[4] 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.

Table E.S.1. Present Value of Per Unit and WAP Program Health-Related Benefits of Weatherization

	Total	Total (Value of Life Excluded)	Tier 1		Tier 2		Tier 3	
			Societal	Household	Societal	Household	Societal	Household
Asthma	$2,009	-	$1,852	$157				
Thermal Stress-Cold	$3,911	$172	$3,892	$19				
Thermal Stress-Heat	$870	$85	$855	$15				
Food Assistance Reduction	$832	-	$832					
Reduction in Missed Days at Work	$201	-	$40	$161				
CO poisoning	$154	$7			$153	$1		
Improvement in Prescription Adherence	$1,929	-			$1,929	-		
Reduction in Use of Short-Term Loans	$71	-			-	$71		
Home Fires	$831	$175					$768	$63
Increased Productivity at Work Due to Improved Sleep	$1,813	-					$1,813	-
Increased Productivity at Home Due to Improved Sleep	$1,329	-					-	$1,329
Reduction in Low-Birth Weight Babies from Heat-or-Eat Dilemma	$198	-					$198	-
Total by Tiers (Present Value Per Unit)	$14,148	-	$7,471	$352	$2,082	$72	$2,779	$1,392
			$7,823		$2,154		$4,171	
Total by Tiers (Present Value WAP Program)	$1,136,883,221	-	$600,333,094	$28,295,957	$167,310,541	$5,766,863.04	$223,324,724.16	$111,878,910.72
			$628,629,051		$173,077,404		$335,176,766	

1. INTRODUCTION

This report describes and monetizes numerous health and household related benefits attributable to the weatherization of low-income homes by the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP). WAP was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of the Program as currently stated in the Code of Federal Regulations (CFR) 10CRF 440.1 is "to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden." (Code of Federal Regulations, 2011) To be eligible for the Program in PY 2008, households had to meet one of two criteria: income at 150% of the federal poverty rate or income 60% or less of the state medium income. The federal threshold was raised to 200% in 2009.

DOE provides grants to Grantees (i.e., states, territories, District of Columbia, a small number of Tribes), and the Grantees provide grants to their Subgrantees (e.g.,, local weatherization agencies) to do the actual weatherization work. DOE allows Grantees and Subgrantees to leverage their DOE funding to attract additional funding for weatherization. Prior to weatherization, all homes receive an energy audit to determine what measures should be installed in each specific home. Energy auditors use DOE approved computerized audit tools, priority lists, and sometimes both. The priority lists allow Subgrantees to install measures that are known to be generally cost-effective without having to resort to time-consuming computerized audits. Auditors employ a range of diagnostic tests to support their assessments. The most common diagnostic measure is the blower door test. Essentially, a machine that includes a fan, a pressure measurement instrument and a mounting system is attached to an outside door. The test measures the airtightness of a home or building and assists with locating air leakage pathways.

Weatherization programs provide three general types of measures and services to clients: home improvements to save energy, home improvements to address health and safety risks, and client education. To be considered for installation, each energy conservation measure needs to pass a Savings-to-Investment Ratio (SIR) test, where the present value (PV) of the energy cost savings over the life of the measure (e.g.,, 20 years) needs to exceed the PV of its cost (i.e., SIR >= 1.0).

During PY 2008, states and agencies were constrained to spend an average of $3500 of DOE funds per weatherized home and were allowed to invest a small amount of money (~15%) to address health and safety issues (e.g., repair/replace a leaky gas furnace). It is common for agencies to encounter homes that are in such poor physical condition structurally that weatherization would have virtually no impact on energy consumption or pose health and safety risks to agency staff. In those cases, weatherization may be deferred. The homes can re-enter the weatherization queue once the household has addressed the reason(s) for the deferral.

After the audit is complete, the agency implements its weatherization model. There are two dominant models. In the first, agencies use in-house crews to do the weatherization work. In the other, agencies hire private-sector contractors. Most agencies that use in-house crews contract out for heating and cooling system repair and replacement work. Most agencies that use contractors will use in-house staff to conduct the audits. Within this general program space an active, diverse, and innovative national weatherization network has evolved.[5] After weatherization work is completed, the agencies are required to inspect all weatherized homes. To address conflict-of-interest issues, whenever possible inspectors do not inspect

[5] Tonn, Rose and Hawkins (2014) have written a set of case studies about local weatherization agencies that aptly describes this diversity.

homes they had initially audited. It should be noted that state weatherization staff and DOE Project Officers also inspect a sample of weatherized homes.

This report is one of approximately forty reports coming out of two evaluations of WAP being conducted by Oak Ridge National Laboratory (ORNL) at the direction of DOE. The first evaluation, known as the Retrospective Evaluation, focuses on the 2008 WAP Program Year (PY). The second evaluation, called the ARRA Period Evaluation, focuses on WAP Program Year 2010.[6] These program years were chosen as the subjects of the evaluations because they represent two distinct phases in the history of the Program. During PY 2008, the Program supported the weatherization of approximately 100,000 households using Federal appropriations of approximately $250 million. This can be regarded as a baseline level of expenditure. PY 2010, however, fell in the middle of the American Recovery and Reinvestment Act of 2009 (ARRA) period, when the Program experienced a dramatic jump in funding to $5 billion, with the expectation that between 600,000 and 1,000,000 homes would be weatherized in a three- to four-year period. The two efforts evaluate what are essentially two very different programs; the comparison will yield useful information for program-management purposes.

It is argued that in addition to households benefitting from lower energy bills, households as well as society and ratepayers also benefit in many other ways from this program. The beneficial impacts of low-income weatherization on human health can be broad and deep. It is well known that weatherization directly addresses CO poisoning from combustion appliances and reduces fires and fire damage through the replacement of furnaces, cleaning of dryer vents, and installation of smoke alarms. Lead safe weatherization is practiced in homes built before 1978 to protect occupants from lead dust possibly generated from the replacement of windows and the drilling of holes in walls and ceilings. New weatherization guidelines deal directly with ventilation, which could have major benefits for indoor air quality. Incidental health and safety repairs can address minor moisture problems, address electrical fire risks, and reduce trip and fall hazards. In addition to these well-established ancillary benefits, the Program and its evaluators continue to unearth and attribute potential ways weatherization can benefit human health beyond those previously claimed.

Section 2.0 contains emerging research within fields such as environmental epidemiology, exposure science, and indoor environmental quality associated with weatherization and non-energy benefits. Extended discussions on how weatherization can impact household health and safety and the well-being of occupants are provided as well as the non-energy benefit conceptual framework used in this study.

Recipients of weatherization services were surveyed just before their homes were weatherized and one to two years post-weatherization. The national occupant survey contained numerous health and safety related questions and is discussed further in Section 3.1. Descriptive statistics derived from the surveys are presented in Section 3.2. An innovative, in-depth statistical analysis that links the impacts of weatherization on mental health, physical health, and sleep/rest is presented in Section 3.3. Then, Section 3.4 presents in-depth analyses of the relationships between weatherization and asthma symptoms.

Section 4 focuses on the monetization of non-energy, health-related benefits. Similar to Section 3, this section also has two parts. The first presents the results of a series of household expenditure benefit survey questions directly put to respondents post-weatherization. Then, Section 4.2 presents the analytical methods used to monetize eleven different health and safety benefits and household-related benefits attributable to weatherization (e.g.,, reductions in CO poisoning and thermal stress). It should be noted that the benefits are grouped into three tiers, based on a comprehensive assessment of the factors that contribute to their accuracy. The tier framework is discussed more in this section of the report and is

[6] All reports written to support these two evaluations will be published by Oak Ridge National Laboratory and will be posted at http://weatherization.ornl.gov

presented in detail in Appendix A. Also presented in Appendix A are the assessments for each non-energy benefit. Conclusions and avenues for future research in this area are presented in Section 5.0.

2. NON-ENERGY BENEFITS OF LOW-INCOME WEATHERIZATION: CONCEPTUAL FRAMEWORK

2.1 OVERVIEW OF NON-ENERGY BENEFITS

Energy poverty is an issue of worldwide concern (Braubach et al. 2011; Liddell and Morris 2010; Hernandez and Bird 2010). It is widely recognized that the weatherization of low-income homes produces a plethora of benefits beyond direct energy savings (Skumatz 2011; Skumatz and Gardner 2004; Amann 2006; Schweitzer and Tonn 2001; Riggert et al. 1999). In fact, non-energy benefits attributable to WAP were estimated as part of its last evaluation over two decades ago (Brown et al. 1993).Typically, non-energy benefits (NEBs), sometimes also referred to as non-energy impacts (NEIs), are bucketed into three general benefit categories: household, societal, and ratepayers. Examples of NEBs in each of these categories include: reduced incidences of carbon monoxide (CO) poisoning, reduced utility bill payment arrearages, and reduced emissions of greenhouse gases.

This report only focuses on health and safety-related and household income non-energy benefits that accrue directly to households and indirectly to society[7] (Breysse et al. 2014; Gilbertson et al. 2012; Howden-Chapman and Chapman 2012; Howden-Chapman et al 2008; Telfar et al. 2011; Tohn and Wilson, 2012; Levy et al. 2003; Jackson et al. 2011; Kuholski et al. 2010). Macro-economic, environmental and ratepayer benefits are monetized in separate reports as well as a summary report entitled *Weatherization Works*.[8] Our understanding of the potential impacts of weatherization on human health has grown in recent years, based in part upon research advances in fields such as environmental epidemiology, exposure science, and indoor environmental quality. To set the stage for the balance of this report, this section next summarizes these emerging research findings with the intent of describing the complex relationships between weatherization and: climate impacts on occupants; outdoor air pollution; and indoor air pollution. The section concludes with a discussion about the relationships between weatherization and well-being in general and then weatherization as a means to mitigate noise pollution in particular.

Weatherization and Climate Impacts on Occupants

The weatherization community in the U.S. is sensitive to improving the comfort of homes while still saving energy. However, emerging research is showing that healthy indoor temperatures, specifically during the winter, may need to be higher than previously thought. For example, the World Health Organization (WHO) states that healthy indoor temperatures are 20^{o}C (68^{o}F) in the living-room and 18^{o}C (64.4^{o}F) in other occupied rooms. Additionally, health risks to the elderly are reduced if internal dwelling temperatures are maintained at a higher level of around 24^{o}C (75.2^{o}F) (International Energy Agency 2013). For purpose of reference, an Indoor Environmental Quality (IEQ) study that was undertaken as part of national evaluations of WAP measured indoor air temperatures in the living rooms of participating low-income households to be approximately 21.1^{o}C (70^{o}F) pre- and post-weatherization (Pigg et al. 2014). This is fine for most households but less than satisfactory for elderly households. Despite the concern that this increase in home temperature to ensure a healthy living space for this population would "take back" some of the energy saved, occupants would be able to maintain that healthy temperature with less energy consumption than they would have pre-weatherization as a result of air sealing, insulation and heating equipment efficiency measures.

We believe that a less recognized but important benefit of weatherization is the reduction of thermal, heat and cold, stress on humans caused by exposure to extreme indoor thermal conditions. Thermal conditions

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[7] It should be noted that this analysis focuses on short-term non-energy benefits - up to 10 years. Long-term non-energy impacts are worthy of future research.
[8] All reports will be published by Oak Ridge National Laboratory and can be located at http://weatherization.ornl.gov.

can have significant adverse effects on health and mortality especially within the vulnerable populations that WAP serves. The effects of heat are amplified in the elderly, pregnant women, and infants (Center for Disease Control and Prevention (CDC) 2005). People with cardiovascular or respiratory disease, diabetes, obesity, chronic mental disorders, limited mobility, or other preexisting medical conditions such as asthma are at greater risk from heat exposure (CDC 2005). Additional risk factors for heat-related mortality include social isolation, low socioeconomic status, limited educational attainment, poor housing, lack of access to air conditioning, and less availability of health care services (Huang 2011). Several of these risk factors are present within the WAP population. Future drivers of heat-related mortality should also be recognized: an increase in housing density; more crowding from increased numbers of occupants within homes; increased population in warmer, inland areas; an increase in energy prices; the urban heat island effect; and an aging population (Phillips 2014).

Over the last ten years in the U.S., heat waves have been responsible for the greatest number of deaths from any type of natural disaster; on average 1,500 people die per year of heat-related causes in the top 15 largest U.S. cities (WHO 2003). Death rates are projected to increase nonlinearly in the coming decades as climate change is forecast to increase the frequency of extreme weather events (see Figure 2.1) with the overall temperature distribution shifting away from the colder extremes (O'Neill 2009). Evenings are already becoming warmer and more humid, minimizing the respite provided by sundown; worsening outside air pollution will force households to keep their windows closed more often, thereby reducing natural ventilation; and the average duration and frequency of power outages is increasing during which existing cooling systems are rendered useless (Phillips 2014).

The extreme heat waves that hit Chicago in 1995 and W. Europe in 2003 resulted in thousands of deaths. The Chicago heat wave caused to 500 heat-related deaths and 3300 excess emergency admissions (WHO 2003). In France, over a five day period temperatures increased to 99^{o}F from the average maximum temperature of 77^{o}F and did not drop for another ten days; close to 15,000 excess deaths directly related to hyperthermia, heatstroke, and dehydration were observed over this time (Foulet et al. 2006). A recent study of heat-related deaths in New York City from the period of 2006 to 2013 found a statistical correlation between heat-related mortality and African Americans living in public housing; a majority of the victims died in their homes. Another recent study took on the task of forecasting heat related deaths in the Eastern U.S for the year 2057. Under one very probable IPCC (Intergovernmental Panel on Climate Change) emissions scenario, the number of heat related deaths would increase by over 4,000 annually (Wu et al. 2013).

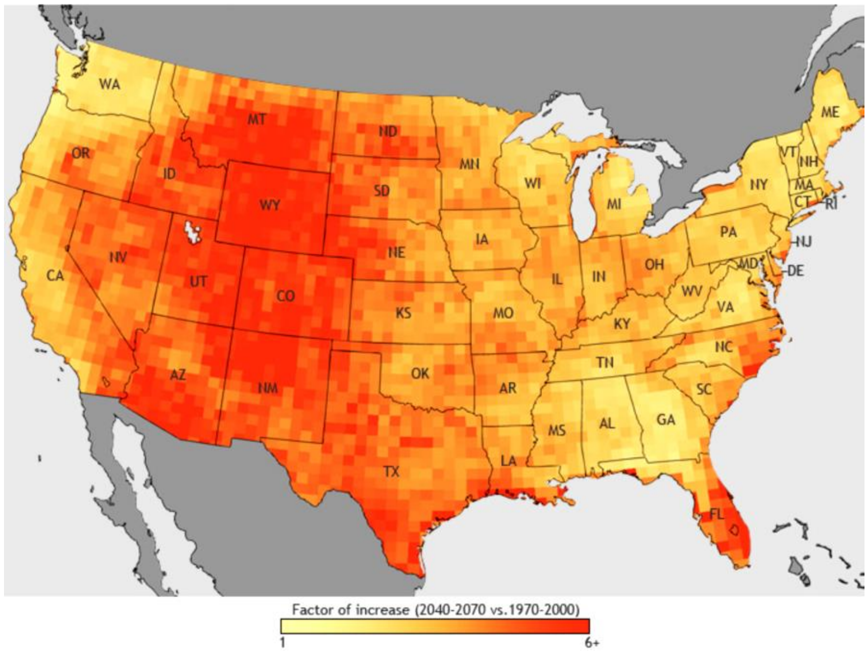

Figure 2.1. Going from yellow to red, the colors on this map show the projected ratio of total heat-wave days per summer (frequency times duration) in the mid-21st century compared to the end of the 20th century.[9]

Huang (1996) reported findings from a computer simulation model revealing the potential for heat wave mitigation through weatherization. The model simulated indoor temperatures in top floor units of a two-story multifamily building without air conditioning. Two simulations were run; one with windows closed and the other with windows open. Simulations were repeated with weatherization measures installed (see Figure 2.2). Findings revealed that the "top-floor temperatures reached 108°F and remained high even after the outdoor temperatures had started to drop. The addition of attic insulation, white paint on the roof, and open windows brought top-floor temperatures in line with outdoor temperatures."[10] Thus, one can argue that weatherization could help to significantly reduce the number of forecasted deaths caused by extreme heat exposure.[11]

[9] National Oceanic and Atmospheric Association (NOAA); www.climate.gov

[10] Traditional WAP allowable expenses do not typically include 'cool roofs'; however, some weatherization agencies do install this measure in conjunction with WAP through leveraged funds and partnerships.

[11] In addition to being a climate change adaptation measure, weatherization can also help mitigate climate change by reducing the consumption of fossil fuels.

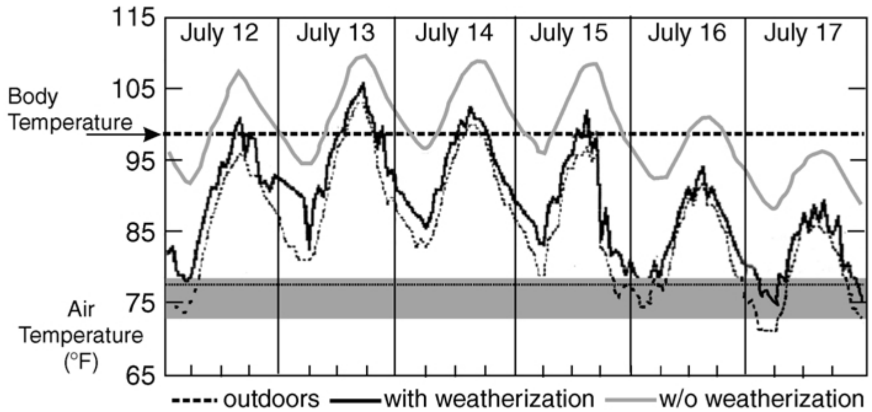

Figure 2.2. Computer-simulated indoor temperature (pre- and post- weatherization) in top floor of prototypical 1940s constructed multi-story apartment building in Chicago during the July 1995 heat wave.

Weatherization as a Barrier to Outdoor Air Pollution

At a recent international conference in Basel, Switzerland, a keynote speaker stated that almost one quarter of the diseases that plague humankind are attributable to environmental risks and can be prevented. According to recent results from the World Health Organization's Global Burden of Disease Project, risks to human health are shifting away from acute causes (e.g., influenza) to more chronic causes (e.g., diabetes, cardiac heart disease). Epidemiologists express concern about the synergistic interactions among substances that humans are regularly exposed to, so much so that a new concept has emerged in this field: the exposome. The exposome is an exhaustive accounting of all of the cumulative, potentially harmful environmental exposures from birth to death. This section addresses exposures to outdoor air pollution that could be ameliorated by weatherization. The next section addresses the topic of indoor air pollution.

The major outdoor air pollutants -- tropospheric ozone, particulate matter, nitrogen dioxide, sulfur dioxide, mercury, lead and other toxic substances -- can have serious impacts on human health. Common health impacts include respiratory disease such as asthma, cardiovascular disease, lung cancer, and stroke. Recent research suggests that outdoor air pollution may also:

- Exacerbate diabetes (Chen et al. 2013)[12]
- Exacerbate obesity (Meng et al. 2013)[13]
- Cause hypertension (Cheng 2013)
- Cause inflammation (Siponen 2013)
- Contribute to prenatal insult, pre-term and low-birth-weight birth (Frank et al. 2006)
- Impact leukocyte telomere length (Hart et al. 2013)
- Impact neurodevelopment (Kim et al. 2013)
- Contribute to breast cancer (Reynolds 2013)

Air sealing can prevent outdoor air pollutants mentioned above from entering homes, thereby reducing the incidence of health risks mentioned. For example, modest improvements to building envelope tightness and ventilation in Finland reduced particulate matter exposure among building occupants by

[12] Diabetics appear to be more sensitive to air pollution and animal studies have found a statistical relationship between $PM_{2.5}$ and diabetes.
[13] A recent California Health Interview Survey study found a statistical relationship between air pollution and being overweight.

20%.[14] Air sealing can also prevent the infiltration of less well recognized but no less harmful substances, such as pesticides and herbicides, and toxics released from hazardous waste spills and other accidents.

Climate change has the potential to worsen air pollution. For example, a warmer atmosphere is expected to increase the levels of tropospheric ozone (Union of Concerned Scientists 2011). Extended droughts could lead to even more forest fires, thereby increasing particulate matter in the outdoor air. The Environmental Protection Agency (EPA) reports that, "Climate change is projected to increase the extent, intensity, and frequency of wildfires in certain areas of the country."[15] Climate change is already leading to changes in the distribution, location, and range of various plant species. As plants, and especially as flowering plants, relocate, people will be exposed to new aeroallergens, which in turn, could worsen allergies and asthma or other respiratory diseases and infections (Vardoulakis 2013). From this expanded perspective, weatherization (e.g.,, air sealing the building envelope thereby preventing the infiltration of outdoor air) can deal with these current outdoor air pollution concerns and projected impacts of climate change on outdoor air quality.

Weatherization and Indoor Environmental Quality (IEQ)

As noted above, weatherization programs are quite attentive to indoor environmental quality, with respect to CO, NO_2, lead, mold and moisture. ORNL's IEQ study found CO levels from combustion systems reduced post-weatherization. Unvented portable propane heaters are dealt with expeditiously to address potential exposure to high levels of CO. There is also growing concern within the health and building science communities regarding the emissions of NO_2 from unvented gas cook stoves or the use of unvented combustion space heaters. Range hoods can be installed and vented outdoors to provide localized ventilation in homes where this is logistically feasible. Post-weatherization, the number of Program respondents that reported using a cook stove exhaust fan regularly increased by 8%.

Delving deeper into the relationships between IEQ and human health, epidemiologists, exposure scientists and others are currently conducting research that suggests indoor exposure to ***chemicals*** may be a more important source of asthma triggers than the usual suspects commonly referred to as environmental asthma triggers (e.g., mold/moisture, cockroach and rodent allergens, dust mites) (Bornehag and Whyatt 2013). Manufactured chemicals and heavy metals inside the home may have been introduced into the home through sources such as building materials, solvents, furniture, and plastics or they may have infiltrated from outdoors (e.g., particulate matter from combustion, agricultural dust). Epidemiologists have concluded that the majority of human exposure to manufactured chemicals occurs from inside the home (Little 2013). It was reported that there are over 100,000 industrial chemicals on the market, suggesting a real possibility of impacts if even a small percentage of these chemicals find their way into homes with persons vulnerable to the potentially harmful effects of these substances (Kolossa-Gehring 2013).

Epidemiological research also suggests a relationship between exposure to manufactured chemicals and heavy metals inside the home and their adverse health impacts beyond asthma. Inhalation of such substances has been linked to inflammation, oxidative stress, thrombosis, and autonomic dysfunction. Exposure to indoor air pollutants has been tied to pneumonia in children, multiple sclerosis, male infertility, hypertension, cerebrovascular events, and neurodevelopment issues in children (Weschler 2013).

One pathway for exposure to these chemicals and heavy metals is through dust. In addition to substantial amounts of squamous (human skin cells), household dust may contain a wide range of contaminants harmful to human health including but not limited to, flame retardants, persistent organic compounds (POCs), semi-volatile organic compounds (SVOCs) released from vinyl flooring, and other manufactured chemicals. One such substance is a plasticizer (phthalate) found in toys and other products. Exposure to

[14] IEA (2013).
[15] http://www.epa.gov/climatechange/impacts-adaptation/forests.html

phthalates and other endocrine disrupting chemicals is statistically correlated to respiratory diseases and infections, and can impact reproductive health (Bornehag and Whyatt 2013). Occupants are also increasingly inhaling ultra-fine particles and nano-particles that are shed off of various consumer products. Residue from environmental tobacco smoke (known as third-hand smoke) and even from the illegal production of methamphetamine by previous residents are rising on the radar of those worried about the impacts of indoor pollutants on human health over time.

Current research in this field suggests that the more dust in the environment the greater chance of exposure to these contaminants through inhalation, ingestion, or skin absorption. Dust from the outdoors may infiltrate the home through open windows, leaky doorframes, and other air leaks in the building's infrastructure. Dust load samples collected from pre-weatherized homes have contained manufactured chemicals such as DDT, and heavy metals such as lead (Weschler 2013). They also contain various speciation of particulate matter ($PM_{2.5}$ and PM_{10}). These are known contributors and triggers for adverse health impacts and diseases such as poisoning, asthma and other respiratory illness, cancer, cardio-vascular diseases, birth defects and premature deaths. Weatherization directly addresses many of these indoor environmental quality issues through dust-reduction measures, such as air sealing, the cleaning and replacement of air filters (including HEPA filters) on air supply lines, proper whole-house and localized ventilation, dryer venting, and by implementing lead-safe weatherization practices.

Drafts in a home may indicate how well sealed the home is from infiltration of outdoor particulate matter. Respondents to the national occupant survey reported that weatherization reduces drafts (see Table 3.2). Also supporting this observation are findings from ORNL's social network study, "Weatherization Experiences," another component of the national WAP evaluations (Rose et al. 2014). Members of social networks who had weatherization work completed at the suggestion of other WAP recipients reported observations related to the indoor environmental quality post-weatherization. Of those who had weatherization work completed through WAP, 55% reported less drafts in the home and 44% of respondents reported the home being less dusty.

Weatherization, Mental Health, and Well-Being

Low-income weatherization can reduce poverty-related stressors faced by occupants as a result of direct energy and non-energy related benefits. Chronic stress as it relates to exposure to psychosocial stress[16] is recognized as a symptom of poverty. Chronic stress is an evidence-based risk factor for adverse health implications associated with the release of stress hormones, in particular, cortisol. High doses of cortisol released as a result of chronic stress correlates with a variety of health problems including cardiovascular disease, asthma, obesity, and anxiety disorders (National Institute of Health 2002). Conversely, of those Americans who reported having a major stressful event in the past year (49%), 43 percent reported that experience being related to health, and those identifying as being in poor health were twice as likely (60%) to report being under a "great deal" of stress within the past month (NPR 2014).The same poll finds that 36% of households with an income < $20,000 reported experiencing high stress levels within the past month. Research presented at a recent Roundtable on the Health and Well-Being Impacts of Weatherization on Human Health hosted by the International Energy Agency found that it only takes a few stressors in one's life to have a significant negative impact on mental health and that the detrimental effect of adding stressors seems to be exponential, not linear (Lidell 2013).

WAP addresses home energy security and fuel poverty issues through the reduction of financial stress associated with home energy affordability and improvement in the perceived control over and actual improved IEQ of the home. Reductions in home energy bills offer both the perception of home energy security and increased flexibility with the family budget with less family income being devoted to home energy. When energy savings are achieved through WAP, the household is in a position to spend the money saved on other necessities (See Tables 3.11-3.13) (Frank et al. 2006; Bhattacharya 2003). The

[16] Psychosocial stress is experienced when individuals face complex and stressful living conditions and can be expressed through feelings of anxiety, depression, high blood pressure and insomnia.

occupant survey also inquired about energy affordability pre- and post-weatherization. Fewer households experience service disconnect notices, service disconnections, running out of bulk fuel (e.g.,, fuel oil, kerosene), and having to pay less than the amount owed on their utility bill. Having more funds to pay any type of bills seems to have led respondents to make less use of short-term, high interest loans (e.g.,, the occupant survey showed that the use of payday loans, tax anticipation loans, and pawn shops all decreased post-weatherization, See Table 3.13), thereby reducing this type of expense as well. It should also be noted that the national occupant survey respondents reported sleeping better, and enjoyed more days being “full of energy” and “mentally healthy” (See Table 3.4).

In addition to this energy security benefit, weatherization has also been shown to address food security issues. The occupant survey results indicate that food worries are also reduced post-weatherization (See Table 3.12). In addition to reducing stress over food issues post-weatherization, occupants may also experience a decrease in stress related to lack of control over the ability to maintain comfortable temperatures for themselves and other household members. The national occupant survey found that 78% of respondents reported their homes being comfortable in the winter post-weatherization versus 58% pre-weatherization, despite the fact that both groups reported similar indoor temperature settings, as noted above.[17] The results were 70% post-weatherization versus 55% pre-weatherization in the summer (Carroll et al. 2014a). A UK study indicated a 40% reduction in mental stress following central-heating and insulation upgrades. Those who reported being ‘cold’ or ‘too cold to be comfortable’ were 75% more likely to be later diagnosed as under stress.[18] Evidence suggests that the potential for mental health improvements from energy efficiency is significant; improved housing has been associated with a 30% to 60% improvement in mental health.[19]

Poor IEQ is another evidence-based risk to human health. Individuals are vulnerable to the effects of poor IEQ resulting from exposure to gas leaks, emissions from combustion appliances, mold and other allergens, asthma triggers, and infestations of pests and rodents. Problematic IEQ has been linked to depression and anxiety. Other physical effects of exposure to poor IEQ such as asthma and allergies may result in loss of productivity at home and work either through absenteeism or “presenteeism.”[20] Loss of productivity through absenteeism may result in financial stress. Family dysfunction as a result of inhibited productivity in the home can also lead to chronic stress through increased dependence on formal and informal social networks for support and perceived lack of control and uncertainty around meeting the basic physiological needs of household members.

Family dysfunction and symptoms of parental depression and psychosocial stress can then lead to *child* exposure to psycho-social stress. Family functioning and well-being promotes secure attachment between caregivers and children, reducing both parental and child exposure to psychosocial stress and allows children and adults to tend to educational and professional needs. Insecure or dysfunctional attachment patterns between children and parents can result in the disruption of child developmental milestones, low self-confidence, -esteem, and -worth and may interfere with a child’s ability to develop schemas around healthy attachments to others including other adults, peers and future offspring (Wong et al. 2002; Jacobsen and Hofmann 1997). Children with observed insecure or dysfunctional attachment and developmental immaturity are at greater risk for poor school performance and unruly, delinquent and sexually risky behaviors having impacts at both household and societal levels (Levi and Orlans 2000; Coleman 2003). A recent study conducted through the MacArthur Foundation’s How Housing Matters Research Initiative found that poor housing quality contributes to emotional and behavioral problems in children and that “much of this association operates through parental stress and parenting behaviors.” (Coley et al. 2013)

[17] This is most likely attributed to air sealing and insulation measures.
[18] IEA Ibid
[19] IEA Ibid
[20] "Presenteeism occurs when an employee goes to work despite a medical illness that will prevent him or her from fully functioning at work,” http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2947637/

Weatherization has the potential to improve these conditions through improvements in such areas as air ventilation, monitoring and installation of measures to improve combustion appliance emissions, installation of CO detectors, venting gas ranges, and reduction in asthma triggers.

By improving the quality of the dwelling, weatherization has the potential to reduce parental stress thereby improving availability and attachment between the caregiver(s) and the children in the home, affording those children the opportunity to better address developmental milestone achievement and improved behavior and performance.

A recent weatherization documentary produced by the Association for Energy Affordability in New York City captured the impact of WAP on tenants living in large multi-family buildings.[21] Many weatherization agencies, such as Northern Manhattan Improvement Corporation, have developed conditions that building owners must satisfy prior to weatherization. For this agency, the building owner must address all NYC Code C Health Violations. One multifamily building occupant described the stress and pressure of residing in an unsafe and unhealthy apartment building before weatherization. She stated she felt as though she was “pressed on,” and that weatherization created a safe living space relieving that pressing sensation. Ameliorating the physiological and psychological symptoms of oppression and poverty through work like weatherization is a benefit that is often overlooked. Thus, weatherization can help break a vicious, negative feedback cycle by improving comfort, and relieve psycho-social stress by creating environments that support general mental health and physical well-being.[22]

Weatherization as a Barrier to Noise Pollution

Weatherization can reduce the penetration of outdoor noise pollution to the indoors through the repair and/or replacement of windows as well as increasing the degree of wall and/or attic insulation. Since the 2011 publication of the World Health Organization’s report, “Burden of Disease for Environmental Noise”, several new studies on traffic noise and physiological and mental health impacts have been published. Epidemiological studies indicate that disruptive noise can be associated with risk for cardiovascular disease (Lekaviciute 2013). Road traffic noise at normal urban levels can lead to stress caused by disruptions in communication, concentration, relaxation and sleep. As discussed previously, an excess of stress hormones (e.g., cortisol) is also an evidence-based risk factor for cardiovascular disease.

The correlation between long-term exposure to noise and Incident (type 2) Diabetes is also being investigated. These studies are revealing that a reduction in sleep quality and duration can result in a decrease in insulin productivity, insulin sensitivity, and problems with glucose and appetite regulation, which are causative factors for Incident Diabetes as well as obesity (Sørensen et al. 2013).

A connection between noise exposure in the residential setting and detrimental effects on sleep and subsequent health is suggested by observational, experimental and epidemiological evidence that has been accumulated over the last decade (Brink 2013). Undisturbed sleep of sufficient length is essential for daytime alertness and performance, health and wellbeing. To remedy these impacts, unhealthy coping mechanisms are often adopted; i.e., increased alcohol intake, smoking, and medications as sleeping aids. Occupants may also be forced to shut their windows in an attempt to reduce noise thereby decreasing natural ventilation and trapping indoor air contaminants and increasing temperatures to an uncomfortable level. In the long run, attempted solutions to mitigate noise levels have the potential to exacerbate health impacts.

We do not know of any study that has extensively measured decreases in the penetration of outdoor noise to the indoors post-weatherization. However, the national occupant survey indicated that noise levels

[21] Association for Energy Affordability. http://aea.us.org/

[22] It should be noted that building owners must also contribute financially to the weatherization of their buildings. This added investment increases the probability that their buildings will receive the full complement of weatherization measures needed to achieve the types of health benefits discussed in this paper.

were reduced post-weatherization as were problems with getting enough sleep and rest (Carroll et al. 2014a).

Weatherization can be a major player in the new world of human health. It has been long known that weatherization provides direct benefits to households and indirect benefits to society and ratepayers. An expanded view, one which takes in new environmental health research, suggests that weatherization could also address human health issues associated with extreme weather events, outdoor air pollution, a broader range of indoor air pollutants, outdoor noise infiltrating indoors, and the mental health and well-being of occupants. The health-related non-energy benefits framework developed to guide this research suggests that weatherization could have a positive ripple effect on household budgets post-weatherization.

Survey results support contentions that weatherization improves the livability of homes and their physical characteristics. Numerous metrics indicate that occupants' health and well-being improved post-weatherization. Households are also better able to afford paying their energy bills, and afford food and prescriptions. The simultaneous equation model results provide insights into the complex relationships between weatherization and quality of life indicators such as bad mental health days, bad physical health days, and days without adequate rest and sleep.

The monetization exercise suggests that weatherization could lead to several thousand dollars of health-related benefits per unit, spread between households and society. The benefits estimated in Section 4.2 may be underestimated because in many instances calculations were restricted to only one person per weatherized household and many potentially monetizable benefits were not included in the analyses.

2.2 COMPREHENSIVE NON-ENERGY BENEFIT FRAMEWORK

The comprehensive non-energy benefit framework presented in this section builds upon the traditional three-component framework and other ideas and concepts mentioned above. Specifically, our framework greatly enhances the household component by recognizing that weatherization can provide many direct and second-order benefits to households and that increases in income can become expenditures that yield societal and ratepayer benefits. Our framework includes these nine components (See Figure 2.3):

- **Household**
  - Physical Changes to Home
  - Income Benefits
  - Health & Safety Benefits
  - Well-Being Benefits
  - Expenditure Benefits
- **Societal**
  - Economic Benefits
  - Environmental Benefits
  - Medical and Social Service Cost Benefits
- **Ratepayer**
  - Reduced Utility Costs

Each component is discussed below. It should be noted that in general homes need to receive a full complement of major weatherization measures (e.g., air sealing, insulation, HVAC replacement/repair, etc.) to generate the types of health benefits described above and herein, though the results presented in Sections 3 and 4 indicate that enough homes received sufficient measures to yield significant non-energy benefits.[23] It should also be noted that while every household is expected to receive energy cost reduction

[23] On average 15% of a weatherization job's cost can be spent on health and safety measures; this percentage can vary state by state. DOE approval is needed if states and agencies intend on exceeding the established threshold. Non-energy benefits are not included in calculations to determine whether measures are cost-effective. States and agencies leverage DOE funds to acquire other funds to support basic weatherization activities and to fund the installation of more health and safety measures. One can

benefits from weatherization, not every household is expected to receive the health and household-income related benefits discussed below. 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.

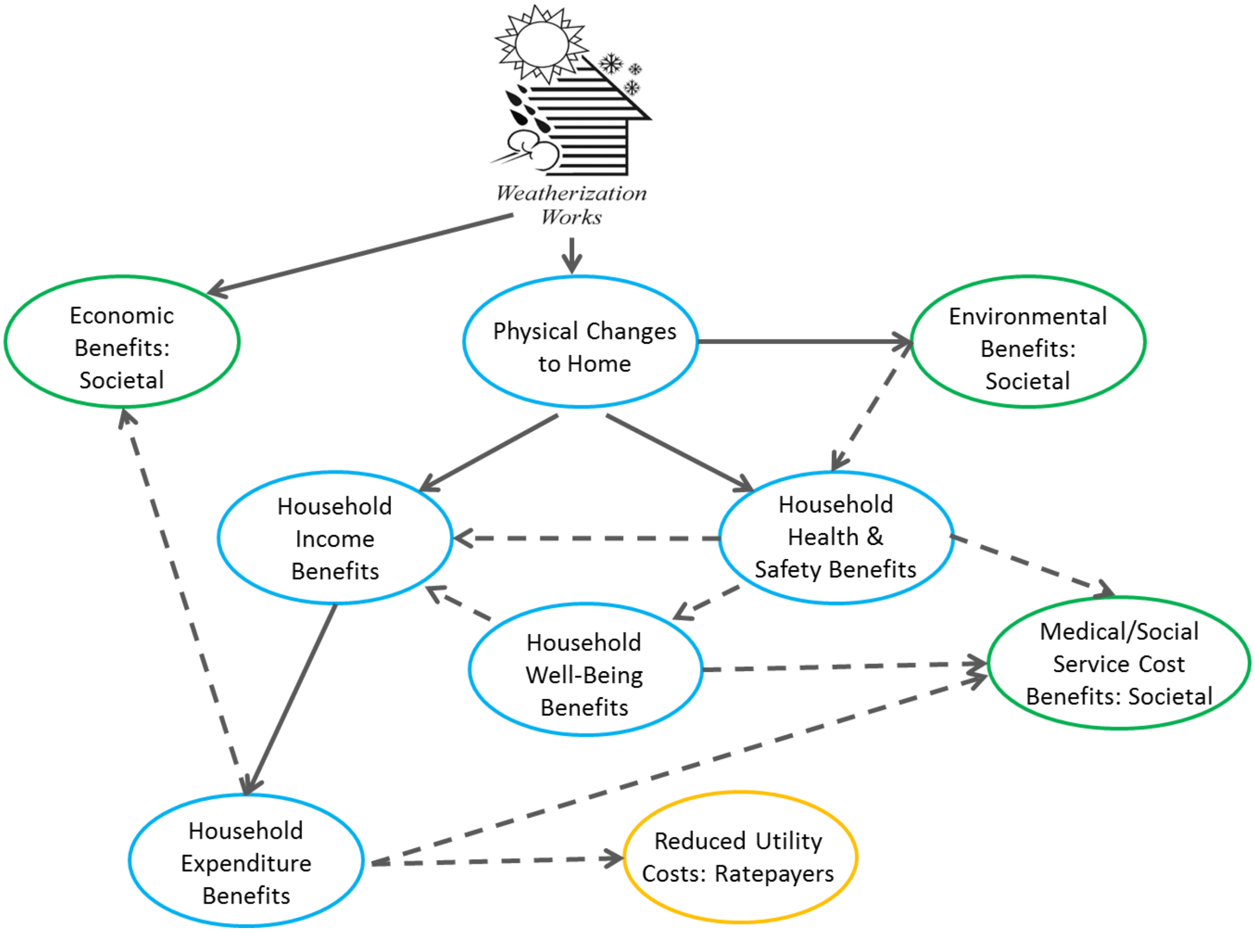

Figure 2.3. Framework for Understanding Non-Energy Benefits (solid lines represent direct, or first-order, pathways; dotted lines represent indirect, or second-order, pathways)

Physical Changes to Home – Weatherization directly improves the physical condition of homes. Weatherization programs across the country tend to install some common measures fairly universally. Nearly all PY 08 weatherized units[24] (91%) received some form of air sealing and 75% had insulation installed (Bensch et al. 2014). (See Table 2.0) Water-heating and space-heating equipment are replaced 65% and 44% of the time, respectively; at times along with installation of mechanical ventilation. Windows and doors are replaced or repaired one-third of the time. The majority of the benefits of weatherization flow from these types of physical changes to the home through energy and cost savings. At a finer-grained level of analysis, households could see an increase in the value of their homes post-weatherization (Nevin et al. 1999). Increases in property values post-weatherization could also spillover to increase the values of other properties in the neighborhood (Drakos 2013).

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argue that leveraging would need to be greatly expanded to achieve the vision of weatherization and human health benefits discussed in this section. Never-the-less, the health benefits attributable to weatherization described in Sections 3 and 4 are still significant.

[24] These percentages include all housing types (e.g. single-family, multifamily and mobile homes). See Blasnik et al. 2013a, 2013b, 2014a and 2014b for breakdowns by housing type.

Table 2.0. Percent of weatherized units receiving work in various measure categories

Measure category	Percent of units
Air sealing	91%
Insulation	75%
Other baseloads	69%
Water-heating system	65%
Space-heating system	44%
HVAC accessories	38%
Windows	37%
Doors	35%
Ventilation	26%
Air-conditioning systems	6%

Environmental Benefits – Energy consumption reductions attributable to weatherization can lead to a wide range of environmental benefits. Reductions in the consumption of fossil fuels in homes and by electric power plants can result in the reductions in emissions of greenhouse gases and criteria air pollutants[25] such as sulfur oxides, nitrogen oxides, and $PM_{2.5}$. Society could also benefit from the reduction in emissions of mercury and other toxins. Of course, as indicated in Figure 2.3, these societal health-related benefits would flow back to the occupants of the weatherized homes as well. Installation of low flow showerheads and faucets can result in the reduced demand for water as well as a reduction in wastewater.

Household Income Benefits – As detailed in a series of impact reports completed through the WAP evaluation, weatherization does result in annual savings on energy and/or bulk fuel bills for households (Blasnick et al. 2014a, 2014b, 2014a, 2014b).[26] In addition to lower energy bills, weatherization has been reported to reduce water bills if crews installed low-flow faucets and showerheads. In addition, the national survey of occupants of weatherized homes, discussed more in Sections 3.0 and 4.0, indicates that respondents reported fewer missed days of work post-weatherization, which minimizes loss of pay especially for employed respondents who do not have sick leave. (See Sect. 4.2.7) This small increase in household income can reduce the need for households to resort to short-term, high interest loans which for this demographic have been reported to be utilized to fund necessary household expenditures, thereby eliminating, or at least reducing, the high-interest fees associated with these loans. (See Sect. 4.2.8) In addition, these households could potentially avoid late payment charges on their utility bills and may also be more able to pay for prescriptions, which ultimately could reduce a range of other out-of-pocket costs. (See Sect. 4.2.9) For example, the occupant survey results suggest that weatherization has a beneficial impact on asthma symptoms. Households with asthma sufferers may have reduced out-of-pocket costs related to reduced asthma symptoms post-weatherization. (See 4.2.4)

Household Health & Safety Benefits – As mentioned earlier, the most commonly installed weatherization measures are insulation, air sealing, heating system repair or replacement, and ventilation. In many cases minor structural repairs are addressed. In combination, weatherized homes are a more comfortable temperature, are less drafty, less dusty, and have improved indoor air quality. As a result, these types of health-related NEBs can accrue to household occupants: fewer hospitalizations due to thermal stress on

[25] Criteria pollutants are a set of air pollutants that cause smog, acid rain, and other health hazards. In most cases, they are the products of the combustion of fossil fuels or industrial processes. The six criteria air contaminants were the first set of pollutants recognized by the United States Environmental Protection Agency as needing standards on a national level; ozone, atmospheric particulate matter, lead, carbon monoxide, sulfur oxides, and nitrogen oxides.

[26] The average annual energy cost savings for a single family, site-built home for homes weatherized during program year 2008 is approximately $280. See Blasnik et al. 2014.

occupants (See Table 3.1 and Sect. 4.2.3); fewer hospitalizations and ED visits due to asthma conditions[27] (See Tables 3.9 and 3.10 in Sect. 4.2.8); and fewer incidences of expectant mothers having to choose between heating and eating (See Table 3.8 and Sect. 4.2.10). Weatherization crews are trained to address combustion issues. All appliances and heating systems that burn fossil fuels are tested for fuel leakage and excessive levels of carbon monoxide. Additionally, as noted above, heating systems as well as hot water systems can be replaced if they are deemed a health and safety risk. Smoke detectors and carbon monoxide monitors are also installed in homes. As a result, homes are safer to live in. The resulting non-energy benefits include reductions in ED visits, hospitalizations, and deaths due to carbon monoxide poisoning and home fires (See Sections 4.2.1 and 4.2.2, respectively).

Household Well-Being Benefits – Examples of well-being benefits experienced from weatherization are simply: feeling more comfortable in ones' home; reduced stress associated with having an increased ability to pay utility bills; feeling healthier; getting more sleep; having more personal energy; and feeling safer due to structural and mobility improvements.

Household Expenditure Benefits – Again referring to Figure 2.3, it is posited that households will spend their increased income in many ways. Results from the national occupant survey suggest that some of the income gains are spent in ways that can benefit both households and society. For example, the national occupant survey indicates that some households have to choose between spending additional money on heating their homes or on food. Previous research has shown that pregnant women facing the heat or eat situation have a higher percentage of low birth weight babies (Frank et al. 2006; Bhattacharya et al. 2003; Cook et al. 2008; FRAC 2005). This household expenditure, then, could reduce the number of low birth weight babies, thereby saving significant amount of money in hospitalization costs during infancy (See Sect. 4.2.10). The survey results also indicate that some households can now afford prescriptions, thereby reducing medical costs resulting from non-compliance with physician directions (See Sect. 4.2.9).

Economic Benefits: Societal – Households will find some ways to expend their increased incomes, as necessary. It is assumed that these expenditures will directly benefit the households. However, some expenditures may also benefit society more than other expenditures, Figure 2.4 below presents some additional detail on this point. For example, expenditures on prescriptions, food, and heating/cooling may improve the health of occupants sufficiently to reduce the draw by these households on health insurance.

In addition, the expenditure of funds to provide weatherization services has direct and indirect societal economic benefits. Most directly, WAP creates jobs for weatherization staff (e.g., home energy auditors, measures installation crew members). The purchase of weatherization measures indirectly supports employment in various sectors of the economy (e.g., firms that produce insulation, manufacture furnaces). As noted above energy cost savings accruable to households can be spent in other ways that may induce the creation of even more jobs. One could argue that the employment benefits may be most enjoyed by economically distressed communities with unemployment concerns. Results from a national survey of weatherization workers suggest that a substantial number of auditors, crew chiefs and crew members (between 42-45%) perceive they would be unemployed without their weatherization jobs (Carroll et al. 2014d).[28]

Medical and Social Service Cost Benefits: Societal – As mentioned previously, weatherization can lead to direct improvements in households' health and safety, sense of well-being and an increase in household income. Through these channels, society may benefit from reduced medical system expenses related to physician office visits, ED visits, and hospitalizations. Being more able to afford food may also reduce the need for food assistance, as also indicated by the survey results (See Sect. 4.2.11). Households are

[27] Air sealing measures may reduce infiltration of pests, outdoor allergens and dust; heating/cooling systems could provide more consistent temperatures; furnace filter replacement can reduce indoor allergens and reduce dust; and proper ventilation can reduce mold and moisture build-up in homes that could trigger asthma symptoms.

[28] Since many of these weatherization workers have a trained skillset that could be transferred to other jobs it does seem unlikely that they would be unemployed long-term. It could be that employees have a difficult time predicting their ability to get a new job quickly when asked about a hypothetical lay-off.

also more able to afford to pay their rent, thereby potentially reducing social services for homeless families.

Ratepayer Benefits – Numerous studies have documented the fact that households whose homes were weatherized are more able to pay their utility bills on time. This provides a benefit to utility ratepayers, as they have less of a need to carry arrearages and pay for utility shut-off activities. It should be noted that households will also experience incremental income benefits because they will not be paying late bill fees or charges for utility shut-offs and re-connection of services.

Other Benefits - Previous research has noted a plethora of additional potential benefits attributable to weatherization. One benefit not included above is a national security benefit. To the degree that weatherization results in less dependence on imported energy, one could argue that national security is enhanced. For example, this benefit could be created by weatherizing homes that heat with imported fuel oil. Another set of benefits relates to the operation of the electricity system. Reductions in electricity use could lead to reduced transmission and distribution costs as well as peak electricity production costs. Weatherization can also be considered a means for climate change mitigation and adaptation. These and other benefits should be the subject of future research.

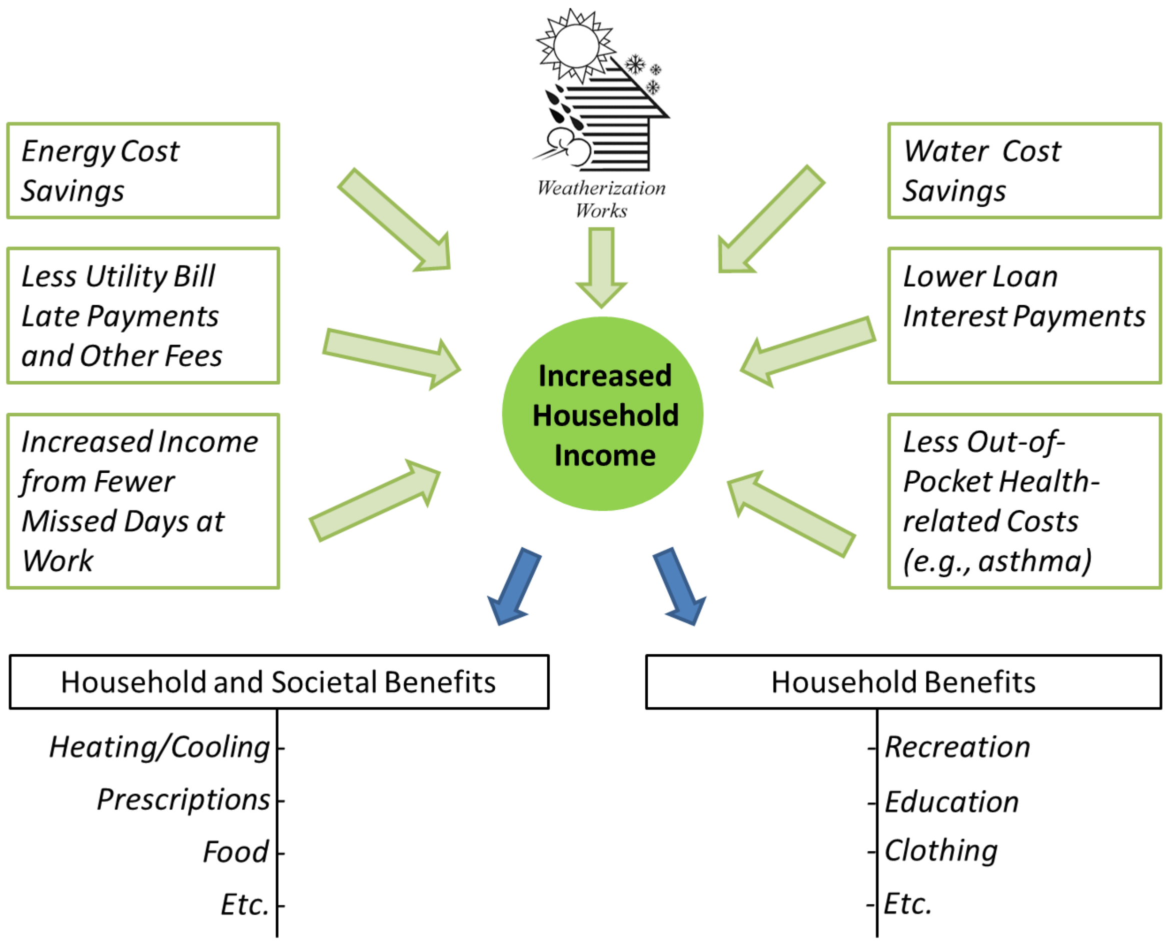

Figure 2.4. Schematic of Household Non-Energy Income and Expenditure Benefits

3. HEALTH BENEFITS OF WEATHERIZATION: STATISTICAL RESULTS

This section of the report presents results from a national survey of WAP clients and a control group that pertain specifically to health and household-related non-energy benefits. The first subsection describes the survey and how it was administered. Section 3.2 below presents descriptive statistics for questions that address home livability, general health, asthma, and household budget issues.[29] Section 3.3 presents a simultaneous equation model that explores the relationships between these three endogenous variables -- mental health, physical health, and sleep/rest -- standard demographic descriptors, and a strong set of exogenous variables that the descriptive statistics suggest are influenced by weatherization. This modeling exercise demonstrates the complex relationships between weatherization and these important quality of life indicators. Section 3.4 presents correlations and a binary logistic regression model that explore relationships between asthma symptoms and weatherization, head of household characteristics, and dwelling characteristics.

3.1 OCCUPANT SURVEY

A national occupant survey instrument was developed and administered, in part, to assess changes in household health and well-being post-weatherization. The approximately 45 minute phone survey contained a set of questions that pertain to health, safety and well-being. The occupant survey was conducted in two phases. In phase 1, a random sample of households close to receiving their energy audits were surveyed, along with a random sample comparison group of households that had been weatherized one-year previously. In phase 2, these same households from both groups were sampled one year to eighteen months later. The survey was implemented as follows:

- As part of the larger evaluation, 400 out of approximately 900 Subgrantees operating across the U.S. in PY 2008 were randomly selected to provide information to assist in the estimation of energy savings in natural gas and electric heated homes. From this subset, 220 were randomly sampled to participate in the occupant survey;

- In 2010, these Subgrantees were asked to furnish lists of single family and mobile homes scheduled for audits at the time of the request and for lists of types of homes weatherized one year previously;[30]

- Homes were randomly selected from aggregated lists for the treatment and comparison groups;

- A computer-assisted telephone survey (CATI) was implemented, with a 70% response rate;

- The samples sizes for the treatment (pre-weatherization) and comparison homes (one year post-weatherization) were 665 and 803, respectively; and

- These same homes were re-surveyed in 2013, yielding 398 responses from the treatment homes and 430 from the comparison homes. [31]

Lastly, it should be noted that 290 households surveyed to be part of the pre-weatherization treatment group had not had their homes weatherized by the time they were contacted to be part of the client satisfaction portion of the occupant survey. It is assumed that weatherization was deferred for these homes. The evaluation team attempted to re-contact this deferral group of homes as part of the second administration of the survey. One hundred-twenty two of these deferral homes participated a second time.

[29] For a more complete reporting of the results from the occupant surveys, please see Carroll et al. (2014a).
[30] Households living in large multi-family buildings were not included in the survey because weatherization of these buildings is quite different. For example, as LMF weatherization job that replaced an old central boiler and a similarly old central hot water heater may not include many if any measures in the individual units.
[31] For more information on the national occupant survey, see Retrospective Evaluation report Carroll et al. (2014a).

When deferral homes are and are not included in the descriptive statistics presented below is clearly indicated.

3.2 DESCRIPTIVE STATISTICS

The following four subsections present descriptive statistics[32] grouped into these categories:

- Home Livability and Other Conditions
- General Health
- Asthma
- Household Budget and Affordability Issues

3.1.1 Home Livability and Other Conditions

This first category addresses to what degree weatherization impacted the livability of homes. Three measures of livability are reported in Table 3.1: how often during the past year the home was kept at unsafe or unhealthy temperatures; and whether any occupant in the home required medical attention because the home was too cold or too hot. This table, like many following tables in these subsections, contains four columns of results. The first two columns present results from surveying the treatment group homes just before they were weatherized (pre-weatherization treatment) and one year to eighteen months after they were weatherized (post-weatherization treatment). A comparison of the results from these two columns provides direct insights into the impacts of weatherization because they involved the same group of households surveyed at different points in time.

The third and fourth columns present results from surveying comparison group homes that had been weatherized one year before the treatment group received weatherization services. The post-weatherization comparison 1 column describes those previously weatherized homes during survey phase 1 and the post-weatherization comparison 2 column describes the comparison group homes surveyed an additional one year to 18 months later. Comparisons between the pre-weatherization treatment and post-weatherization comparison 1 groups also provide useful insights since the data for both groups were collected in the same time period.

Two types of difference of means tests were used on the data in Table 3.1 and elsewhere in this section. An Analysis of Variance (ANOVA) was performed to see if there is a statistically significant difference in the means between continuous variables. Pearson's Chi Square was used for ordinal and dichotomous variables. Statistical tests were conducted over three pairs of variables: pre-weatherization treatment group and post-weatherization treatment group; pre-weatherization treatment group and comparison group 1; and comparison group 1 and comparison group 2. These are identified as (1), (2), and (3) in this table.[33]

The results presented in Table 3.1 suggest that weatherized homes are more livable. Post-weatherization treatment group homes were kept at safer temperatures (e.g., the percentage of treatment homes never kept at unsafe or unhealthy temperatures increased by 12% following weatherization). The results from the surveys of the comparison are very similar to the post-weatherization treatment group. The table indicates that the differences between the treatment groups pre- to post-weatherization are highly statistically significant. The difference between the pre-weatherization treatment group and the post-weatherization comparison 1 group is also highly statistically significant. The difference between the two

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[32] Note: Sample sizes (n) for findings presented in Section 3.2 are not reported for each table (with the exception of section 3.2.3 Asthma) as the (n) differs insignificantly: 99.9% of occupant survey respondents answered all survey questions.

[33] All households surveyed in each group and each survey phase are included in analyses (1) and (3) rather than only homes that completed the survey both times. As noted in Section 2, not every home was characterized by every health-related issue considered here and the health-related issues that households do experience need not occur each year. For example, houses do not experience thermal stress every year. Thus, it was determined to estimate changes between population groups. This decision also allowed for higher sample sizes for the statistical tests.

administrations of the survey to the comparison group is very small and is not statistically significant, which may indicate that livability many not continue to change over time. The results presented in Table 3.1 also suggest that fewer occupants needed medical attention post-weatherization because the homes were too cold or hot. The results for the post-weatherization treatment group and the two comparison groups are consistent.

Table 3.1. Livability of Homes Pre- and Post-Weatherization

	Treatment Group		Comparison Group	
Survey Question	Pre-WX	Post-Wx (1)	1-Year Post (2)	2-Year Post (3)
How often kept home at unsafe or unhealthy temperature the past year (1=almost every month, 4=never)	3.69	3.91***	3.83***	3.85
Needed medical attention because home too cold the past year (1=yes, 0=no)	0.032	0.015	0.021	0.012
Needed medical attention because home too hot the past year (1=yes, 0=no)	0.024	0.015*	0.011	0.007

*** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment; (2) Pre-Wx Treatment vs. 1-Yr Post-Wx Comparison; (3) 1-Yr Post-Wx comparison vs. 2 Yr Post-Wx Comparison

Table 3.2 presents the results from seven questions posed to respondents about the physical condition of their homes pre- and post-weatherization. Each physical condition improved post-weatherization; all of the statistical tests between the pre-weatherization treatment group and the post-weatherization treatment and post-weatherization comparison 1 group are statistically significant. The largest reported change is related to drafts; post-weatherization homes are much less drafty. This is not an unexpected result since over 90% of homes received some sort of air sealing measure during the weatherization process.[34] The results also suggest that insulation, air sealing and other measures can incrementally reduce noise pollution as well as protect homes from infestation from insects and mice. Weatherization, including health and safety measures, also incrementally reduces smells, standing water, and mold in homes (e.g., respondents reporting seeing mold in their homes dropped from 28% pre-weatherization to under 20% post-weatherization).

[34] Please see Bensch et al. (2014) for a detailed description of measures installed in homes.

Table 3.2. Physical Condition of Homes Pre- and Post-Weatherization (Means)

	Treatment Group		Comparison Group	
Survey Question	Pre-WX	Post-Wx (1)	1-Year Post (2)	2-Year Post (3)
How often home too drafty (1= all the time, 4 = never)	2.86	3.60***	3.50***	3.60*
Outdoor noise (1=great deal, 4= none at all)	2.07	2.37***	2.47***	2.42
How infested is home with cockroaches, other insects, spiders (1=extremely infested, 5=not infested at all)	4.19	4.37***	4.37***	4.32
How infested is home with mice (1=extremely infested, 5=not infested at all)	4.61	4.73*	4.73**	4.70
Frequent mildew odor or musty smell (1=yes, 0=no)	.30	.21***	.16***	.16
How often have observed standing water in home (1= never, 5=always)	1.60	1.44**	1.34***	1.31
Have seen mold in home (1=yes, 0=no)	.28	.19**	.19***	.17

***** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment; (2) Pre-Wx Treatment vs. 1-Yr Post-Wx Comparison; (3) 1-Yr Post-Wx comparison vs. 2 Yr Post-Wx Comparison**

3.1.2 General Health

These two sets of results presented above begin to suggest that the physical changes in the homes made through weatherization have the potential to impact the health of occupants. The results in the tables contained in this subsection support this assertion. Table 3.3 contains results of two questions that were only contained in the second administration of the national occupant survey. The questions address overall changes in respondents' health post-weatherization. Over 30% of respondents from both the post-weatherization treatment and post-weatherization comparison 2 groups reported improved health post-weatherization, with most respondents attributing most of the improvements to weatherization. Only about 5% of respondents reported that their health had gotten worse with virtually none of these respondents attributing their conditions to weatherization.

Table 3.3. Overall Changes in Health Since Weatherization

Since your home was weatherized, has the overall health of the members of your household improved, stayed the same, or gotten worse? How much do you think was due to your home being weatherized?			
	Post-Weatherization Treatment	**Post- Weatherization Comparison 2**	**Total**
Number of Respondents	393	428	821
Improved	34%	32%	33%
Attribute All to Wx	*9%*	*10%*	*10%*
Attribute Most to Wx	*13%*	*10%*	*11%*
Attribute Some to Wx	*9%*	*11%*	*10%*
Attribute None to Wx	*2%*	*1%*	*1%*
Refusal	*1%*	*0%*	*<1%*
Stayed the Same	62%	62%	62%
Gotten Worse	4%	6%	5%
Attribute All to Wx	*0%*	*<1%*	*<1%*
Attribute Most to Wx	*0%*	*<1%*	*<1%*
Attribute Some to Wx	*1%*	*1%*	*<1%*
Attribute None to Wx	*3%*	*4%*	*4%*
Refusal	*0%*	*<1%*	*<1%*

The results presented in Table 3.4 provide some details to help explain the reported improvements in health. Respondents were asked about their physical health, mental health, rest and sleep, personal energy, and ability to perform everyday activities for a period of one month prior to the survey. Treatment group respondents reported improved health over these five indicators post-weatherization. For example, respondents reported experiencing approximately one less day of not good physical health and mental health during the previous month. Generally, the post-weatherization comparison group results are consistent with these observations.

Table 3.5 presents descriptive statistics using means for questions that addressed the respondents' health and health conditions of household occupants. Treatment group respondents reported fewer issues with headaches post-weatherization. The households also experienced fewer cases of the flu, persistent colds, and sinus infections post-weatherization. The results are inconclusive with respect to ear infections, respiratory allergies, and bronchitis.

Table 3.4. Changes in General Respondent Health Conditions Post-Weatherization

	Treatment Group		Comparison Group	
Survey Question	**Pre-WX**	**Post-Wx (1)**	**1-Year Post (2)**	**2-Year Post (3)**
Number of days physical health not good last month (0-30)	10.3	5.4***	8.7**	5.4***
Number of days mental health not good last month (0-30)	7.1	3.7***	6.8	3.2***
Number of days did not get enough rest or sleep last month (0-30)	11.7	6.6***	9.7*	5.0***
Number of days felt very healthy and full of energy last month (0-30)	18.5	8.9***	18.5	7.7***
Number of days kept from usual activities last month (0-30)	15.28	4.0***	15.8	3.8***

*** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment; (2) Pre-Wx Treatment vs. 1-Yr Post-Wx Comparison; (3) 1-Yr Post-Wx comparison vs. 2 Yr Post-Wx Comparison

Table 3.5. Changes in Specific Health Conditions Post-Weatherization

	Treatment Group		Comparison Group	
Survey Question	**Pre-WX**	**Post-Wx (1)**	**1-Year Post (2)**	**2-Year Post (3)**
New/more frequent or severe headaches last three months + (1= yes, 0=no)	.20	.16	.16*	.14
Three or more ear infections last year++ (1= yes, 0=no)	.08	.07	.08	.06
Any kind of respiratory allergy last year++ (1= yes, 0=no)	.28	.31	.24	.28
Flu last year++ (1= yes, 0=no)	.22	.18	.18	.16
Persistent cold symptoms lasting more than 14 days last year++ (1= yes, 0=no)	.21	.12***	.19	.14*
Sinus infection or sinusitis last year++ (1= yes, 0=no)	.37	.34	.35	.34
Bronchitis last year++ (1= yes, 0=no)	.23	.22	.23	.19

+ Respondent; ++ Anyone in household; *** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment; (2) Pre-Wx Treatment vs. 1-Yr Post-Wx Comparison; (3) 1-Yr Post-Wx comparison vs. 2 Yr Post-Wx Comparison

3.2.3 Asthma

The next set of statistics pertains to IEQ and psychosocial stress as asthma triggers and their relationship to weatherization. The hypothesis put forth is that weatherization can, as a by-product, reduce the number and potency of home-based environmental asthma triggers, resulting in fewer asthma symptoms, direct medical costs, and indirect costs. Households of low socioeconomic status (SES) are more likely to reside in substandard housing conditions and be exposed to multiple asthma triggers. Note that there is a strong link to genetic susceptibility as well, which makes it even more necessary to address the problem as another perpetuate or symptom of generational poverty.[35] Other moderating factors include race, ethnicity, gender, and age.[36] This analysis explores the impact of weatherization delivered through WAP as a multi-component intervention on the severity and incidence of asthma episodes by addressing multiple triggers in the home environment.[37]

Weatherization measures address multiple evidence-based indoor environmental triggers covered by public health campaigns and community health education programs tasked with reducing asthma morbidity. Figure 3.1 includes evidence-based environmental asthma triggers and a list of potential weatherization measures delivered through WAP that could reduce exposure to environmental triggers from inside the home (e.g., mold, cockroaches, mice, dust, other particulate matter, and by-products of combustion from gas cooking stoves and portable unvented heaters). HVAC replacement, maintenance and accessories, such as HEPA filters, may be included in the weatherization scope of work depending on the needs of the housing unit. This is determined through the energy audit and may be dependent on availability of leveraged resources secured by the weatherization provider for additional health and safety measures. While primarily targeting energy efficiency, these heating equipment measures provide tertiary health benefits by addressing air quality issues caused by combustion by-products and dust. Commonly installed air sealing and insulation measures reduce exposure to extreme hot and cold temperatures, and have the potential to reduce indoor exposure to contaminants generating from the outdoor environment. Improving comfort through air sealing, insulation and heating equipment measures may also reduce the indoor use of unvented portable heaters. Air sealing measures can also save energy while reducing pest infestations and thereby reducing exposure to evidence-based asthma triggers from mice and cockroach generated particulates. Mechanical ventilation measures address moisture related problems (e.g., mold) in the home and may exhaust contaminants generated from the indoor environment (e.g., NO_2 generated from gas cooking stoves) or those that have infiltrated the home from the outdoor environment. Finally, reductions in psychosocial stress related to home energy insecurity and dwelling quality may positively impact the wellbeing and health of persons in the home with asthma.

[35] See Meng et al. (2010)
[36] Ibid.
[37] See Breysse et al. (2014), Krieger. (2010), and Dixon et al. (2009).

 Asthma	WEATHERIZATION WORKS
Environmental Tobacco Smoke (ETS)	Air Sealing
Dust Mites	Insulation
Pollutants from vehicle traffic infiltrating indoors (e.g., diesel exhaust)	Heating system replacement/maintenance/filters
Ozone	AC system replacement/maintenance
Outdoor allergens	Mechanical ventilation
Cockroach allergen	Window replacement/repair
Rodents	Door replacement/repair
Pets (cats and dogs)	Dryer venting
Molds and fungi	Health & Safety testing and measures
Smoke from burning wood	Ground vapor barrier
Indoor VOCs	Energy cost savings
Thermal stress (extreme temps indoors)	Incidental repairs (walls, ceiling, roof)
Severity of the common cold	Referrals to other agencies
Psycho-social stress	
Particulate matter from cooking; NO_2	

Figure 3.1. Evidence-Based Housing-Relating Environmental Asthma Triggers and Weatherization Measures and Impacts[38]

Mitigating exposure to these indoor and outdoor source contaminants and hazards through weatherization contributes to on-going efforts to reduce chronic disease outcomes for households of low-socioeconomic status disproportionately burdened by their effects. Social justice in the context of human health is generally equated with access to health resources and equal opportunity to a healthy life. Determinants for domestic health disparities (health outcomes that impact certain populations to a greater extent than others) have been identified and integrated into social programs tasked with combatting chronic disease in the US.[12] This research study targets two of the factors identified as contributors to asthma as a health disparity; social determinants (households of low SES) and environmental exposures to contaminants (through weatherization).

Table 3.6 characterizes the WAP population with regards to asthma prevalence. Respondents were initially asked if they have *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 in the first phase of the survey 15.7 percent of all respondents reported still having asthma, and 17.5 percent of respondents reported still having asthma during the second phase of the survey.[39] Treatment, comparison and deferral group responses were grouped to most accurately characterize the entire WAP eligible population by using the largest sample available.

[38] This table is not to be used as a matrix. Additional research is necessary to better attribute specific weatherization measures to any changes in asthma morbidity due to any of the specific evidence based asthma triggers presented in this table.
[39] A substantial drop in sample size complicated subsequent asthma-related statistical analyses.

Table 3.6. Characterization of the WAP Population by Asthma[40]

Have you ever been told by a doctor or health professional that you have asthma?	
Survey Phase	% Responses = ***YES***
Phase 1 (2011; n=384/1897)	20.2%
Phase 2 (2013; n=208/948)	21.9%
Do you still have asthma?	
Survey Round	% Responses = ***YES***
Phase 1 (2011; n=298/384)	77.6%
Phase 2 (2013; n=166/203)	81.8%
% of all surveyed WAP respondents who still have asthma	
Phase 1 (2011; n=298/1897)	**15.7%**
Phase 2 (2013; n=166/948)	**17.5%**

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. The "whole asthma sample" includes all respondents reporting they still have asthma at the time of either of the two surveys administered in 2011 and 2013; this includes treatment, comparison and deferral group respondents. Respondents who responded to the survey both pre- and post-weatherization belong to the "paired sample." Analysis was conducted on both samples as the whole asthma sample (n=216[41]) was considerably larger than those in the paired sample (n=93). Households who reported being deferred weatherization were excluded from the samples for analysis as there was no intervention to measure change post-weatherization and they were not included as a comparison group for analysis due to the range of reasons for the deferral of weatherization including structural problems, extreme mold or other moisture issues beyond the scope of weatherization, and unsanitary conditions posing health risks to the weatherization workers.

The following graphic (Figure 3.2) describes the two samples analyzed and the groups within each of the samples. Table 3.7 characterizes the whole WAP sample compared to the WAP whole asthma sample and Table 3.8 characterizes the WAP whole asthma sample compared to the WAP asthma paired sample by demographics. Although no statistical tests were completed, it should be noted that the WAP whole asthma treatment sample appears to diverge both from the entire WAP sample, the comparison group, and the WAP asthma paired sample along many variables. This situation is explored in more depth in Section 3.4 with additional comparisons between the two asthma samples.

[40] Includes treatment, comparison and deferred households. This allows us to best characterize the WAP population
[41] This number reflects the whole asthma sample with the exclusion of the deferral group.

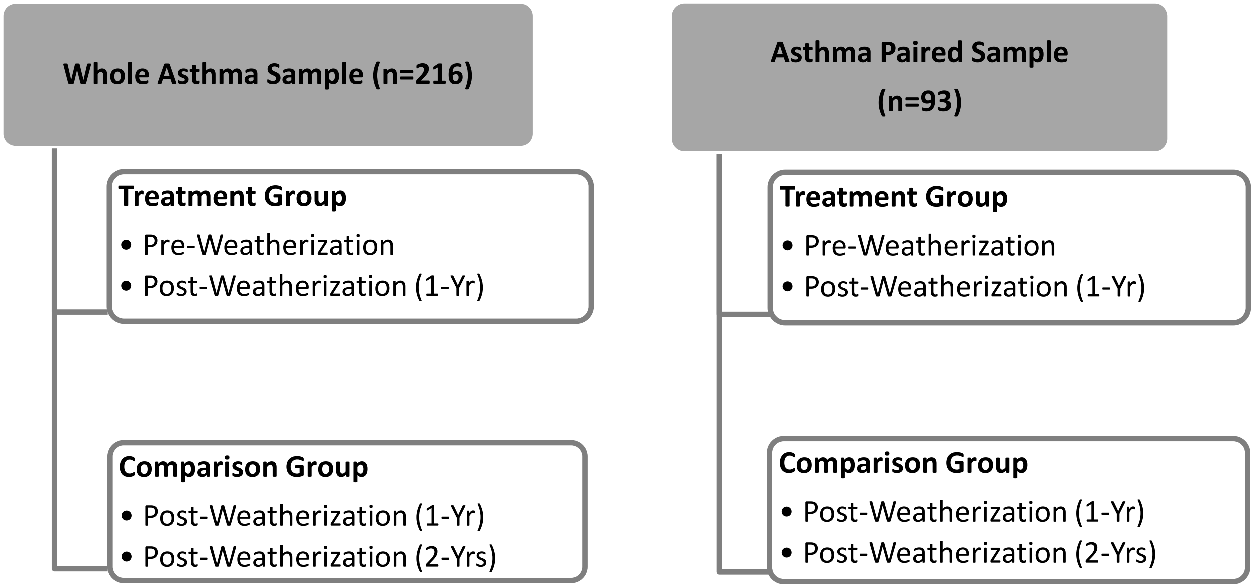


Figure 3.2. Asthma Survey Samples and Groups Used for Analysis

Table 3.7. Characterization of the WAP Whole Sample Compared to the WAP Whole Asthma Sample (Survey Phase 1)

Sample Characteristics By Whole Survey Sample and Asthma population within the whole survey sample	**WAP Sample-Occupant Survey (n=1897*)**	**Asthma Sample-Occupant Survey (n=298*)**
RESPONDENT DEMOGRAPHICS and CHARACTERISTICS		
Elderly (65+)	33.8%	26.4%
Gender=Female	74.0%	77.4%
Black/African American	17.7%	19.1%
Latino/Hispanic Origin	6.8%	5.7%
Not working due to a disability	37.7%	55.0%
Received income from SSI	24.1%	32.3%
Smoke cigarettes	28.7%	32.9%
Smoking allowed inside the home	27.2%	32.9%
ACCESS to HEALTHCARE and AFFORDABILITY		
Had Health Care in last 12months	84.1%	88.9%
Needed Prescription meds but couldn’t afford	29.0%	43.0%
Didn’t fill prescriptions to pay utility bill	23.7%	33.2%
Didn’t pay energy bills to purchase prescriptions	11.3%	17.2%
Needed to see a doctor but couldn’t because of cost	29.6%	33.6%
Household members had trouble paying medical bills	38.2%	44.0%
ENERGY AFFORDABILITY		
Hard or *Very Hard* to pay energy bills	68.2%	76.1%
Did not purchase food to pay energy bill (*Every/Every Other Month*)	9.6%	12.6%
Did not pay energy bill to buy food (*Every/Every Other Month*)	4.8%	7.1%
Pay less than amount owed on energy bill *almost every month*	11.6%	15.8%
Receive disconnect, shut-off or non-delivery notice *almost every month*	6.6%	9.8%
Electricity or natural gas disconnected	14.2%	12.4%
Fuel oil, kerosene, or wood ran out	9.0%	13.4%
Used high interest loan or pawn shop to assist with energy bill	11.6%	15.2%
FOOD INSECURITY		
Receive supplemental nutritional assistance or WIC	54.5%	65.4%
Worried household members would not have nutritious food	20.2%	26.7%
Household member went without food in past 4 weeks	7.5%	8.7%
INCOME		
Mean Income	$20,800	$17,800

*Characterizations of the WAP sample and the WAP asthma sample include households deferred weatherization

Table 3.8. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample by Demographics

	Treatment Group		Comparison Group	
Sample Characteristics by Group	**Whole Asthma Sample (n=93)**	**Paired Sample (n=41)**	**Whole Asthma Sample (n=123)**	**Paired Sample (n=52)**
Gender: Female	73.4%	73.2%	76.4%	84.6%
Black/African American	16.0%	14.6%	14.6%	15.4%
Latino/Hispanic Origin	6.4%	4.9%	4.9%	3.8%
Elderly	22.6%	25.0%	30.9%	36.5%
Health Care Coverage	85.1%	92.7%	91.9%	92.3%
Not working due to disability	52.1%	51.2%	56.9%	50.0%
Received income from SSI	37.2%	34.1%	28.5%	19.2%
Average Income	$19,200	$18,500	$16,600	$16000

The results presented in Tables 3.9 and 3.10 pertain only to respondents who both reported having ever been told by a physician that they had asthma and still believed they had asthma at the time of the survey. The treatment group respondents report visiting the ED and being hospitalized less because of asthma post-weatherization, with the drop in ED visits in the whole asthma sample being statistically significant (11.5%). Again, it should be noted that the treatment group differs from the comparison group with respect to ED and hospitalization patterns suggesting underlying differences (i.e., severity of asthma) between the treatment and comparison groups for this subset of the WAP population surveyed. Additional analysis of survey sample characteristics for the WAP asthma population and the determination of how best to monetize the asthma health benefit of WAP are explored in Section 3.4.

Table 3.9. Changes in Respondent Asthma Related Emergency Department (ED) Visits

% of Respondents Reporting Visit to ED due to asthma (in past 12 months) by Group and by Sample	**ED Visit**	**Difference**
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=93)	15.8%	(-) 11.5%*
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=47)	4.3%	
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year; n=122)	18.9%	(-) 2.8%
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years; n=56)	16.1%	
Asthma Paired Sample-Treatment Group (**Pre-Wx**; n=47)	10.6%	(-) 6.3%
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year; n=47)	4.3%	
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year; n=52)	19.2%	(-) 1.9%
Asthma Paired Sample- Household-Comparison Group (**Post-Wx** 2-years; n=52)	17.3%	

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

Table 3.10. Changes in Respondent Asthma Related Hospitalizations

% of Respondents Reporting Hospitalization due to asthma (in past 12 months) by Group and by Sample	Hospitalization	Difference
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=93)	13.7%	(-) 3.1%
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=47)	10.6%	
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year; n=123)	7.3%	(-) 1.8%
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years; n=55)	5.5%	
Asthma Paired Sample-Treatment Group (**Pre-Wx**; n=47)	17.0%	(-) 6.4%
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year; n=47)	10.6%	
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year; n=52)	5.8%	(+) 0.1%
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years; n=51)	5.9%	

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

3.2.4 Household Budget and Affordability Issues

Table 3.11 moves the discussion from specific health issues to difficulties in paying bills. The conceptual framework presented in Section 2.0 suggests that households should be better able to pay their bills, even if the change is only incremental, due to energy cost savings and a cascade of other small savings. The results presented in this table support this contention. Treatment group respondents reported having less difficulty paying energy bills post-weatherization, and their households were better able to afford prescriptions and follow their prescriptions, see their doctors, and pay health-related bills. Difficulties in affording prescriptions were eased the most; more respondents reported being able to afford prescriptions post-weatherization.

Table 3.11. Difficulties in Paying Energy Bills and Health-Care Expenses Pre- and Post-Weatherization

	Treatment Group		Comparison Group	
Survey Question	**Pre-WX**	**Post-Wx (1)**	**1-Year Post (2)**	**2-Year Post (3)**
How hard is it to pay your energy bills (1= very hard, 5= not at all hard)	2.18	2.88***	2.61***	2.80
Had health care coverage (past 12 months) (1= yes, 0= no)	.83	.84	.87	.87
Household member needed prescription medicines but couldn't afford (1= yes, 0= no)	.33	.22***	.24***	.21
How often didn't fill prescription/took less to pay utility bill (1=every month, 3= every few months, 6= never)	5.28	5.51**	5.51**	5.68
How frequently didn't pay energy bills to purchase prescriptions (1= every month, 3= every few months, 6= never)	5.73	5.77	5.79	5.87*
Needed to see doctor but could not because of cost (1=yes, 0 = n0)	.32	.24**	.25**	.21
Household members had trouble paying medical bills) (1= yes, 0= no)	.41	.32**	.34**	.29

*** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment; (2) Pre-Wx Treatment vs. 1-Yr Post-Wx Comparison; (3) 1-Yr Post-Wx comparison vs. 2 Yr Post-Wx Comparison

Similar to the results just presented, households appeared better able to afford to purchase food post-weatherization and worry less about having food in the home (see Table 3.12). The frequency that households in the treatment group did not purchase energy to purchase food decreased post-weatherization. Another indicator that households were better able to afford food is the result that fewer households received food assistance post-weatherization.

Table 3.12. Food-Related Issues Pre- and Post-Weatherization

	Treatment Group		Comparison Group	
Survey Question	**Pre-WX**	**Post-Wx (1)**	**1-Year Post (2)**	**2-Year Post (3)**
How often not purchased food to pay energy bills past year (1= every month, 3= every few months, 6= never)	5.00	5.23**	5.31***	5.47
How often not paid energy bills to purchase food past year (1= every month, 3= every few months, 6= never)	5.31	5.55**	5.53***	5.62
Household member went without food (past 4 weeks) (1=yes, 0= no)	.07	.05	.06	.05
Worried household members wouldn't have nutritious food (past 4 weeks) (1=yes, 0= no)	.23	.18**	.15***	.15
Received food stamps or WIC assistance past year (1=yes, 0= no)	.56	.50	.50*	.50

*** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment; (2) Pre-Wx Treatment vs. 1-Yr Post-Wx Comparison; (3) 1-Yr Post-Wx comparison vs. 2 Yr Post-Wx Comparison

Table 3.13, presents a few more statistics that suggest that households are better able to pay their bills post-weatherization. The first two rows suggest that treatment group households face fewer situations where they have to trade-off paying their various utility bills. 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 pawnshops.

Table 3.13. Other Indicators of Ability to Pay Bills Pre- and Post-Weatherization

	Treatment Group		Comparison Group	
Survey Question	**Pre-WX**	**Post-Wx (1)**	**1-Year Post (2)**	**2-Year Post (3)**
How often not paid energy bills to pay other utility bills (1= every month, 3= every few months, 6= never)	5.06	5.33*	5.35**	5.39
How often not paid other utilities to pay primary energy bill (1= every month, 3= every few months, 6= never)	5.07	5.38**	5.31***	5.52**
Used payday loan to assist paying energy bill (1= yes, 0= no)	.05	.04	.04	.03
Used tax refund anticipation loan to assist paying energy bill (1= yes, 0= no)	.06	.04	.04*	.02*
Used car title loan to assist paying energy bill (1= yes, 0= no)	.02	.01	.02	.02
Other short term, high-interest loan to assist paying energy bill (1= yes, 0= no)	.03	.03	.02	.02
Used pawn shop to assist paying energy bill (1= yes, 0= no)	.08	.04*	.04**	.03

*** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment; (2) Pre-Wx Treatment vs. 1-Yr Post-Wx Comparison; (3) 1-Yr Post-Wx comparison vs. 2 Yr Post-Wx Comparison

In summary, the results presented above suggest the following post-weatherization benefits:

- Homes are more livable;
- The physical condition of homes is improved;
- These and other improvements lead to improved general health;
- Respondents experience fewer ‘bad’ physical and mental health days;
- Respondents and other household members suffer fewer persistent colds and headaches;
- There are fewer instances of doctor and ED visits, and hospitalizations;
- 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 decreases; tax refunds and pawn shops.

3.3 SIMULTANEOUS REGRESSION EQUATION MODEL RESULTS

The previous section begins to build a picture of how weatherization can positively impact human health. This section again takes advantage of the occupant survey to explore how many of the variables discussed above interact with each other and with weatherization.

A standard approach to explore the interactions amongst variables is regression analysis. Regression models allow researchers to explore relationships between dependent variables and sets of independent variables. In this instance, the research presented below explores the relationships between three high-level descriptors of health-related quality of life – mental health, physical health, and sleep/rest – and many factors that may contribute to or detract from these quality of life indicators. It is further supposed that many of these factors are themselves influenced by weatherization. For example, one could hypothesize that worries about energy bills may adversely impact mental health, a drafty home may adversely impact physical health, and uncomfortable indoor temperatures could adversely impact sleep and rest.

The model presented below actually contains three separate equations, one each for the three main quality of life indicators mentioned above. These three variables are treated as endogenous variables because it is further hypothesized that they could influence each other. For example, poor mental health could adversely impact sleep and rest and visa-versa. In situations where there are multiple equations and the dependent variables are specified in multiple equations, the statistical procedures used to estimate the model need to treat the equations simultaneously. In this case, a procedure called Three-Stage Least Squares (3SLS) was used to estimate the model.[42]

The model was estimated using two survey groups, pre-weatherization treatment and post-weatherization comparison 1. Table 3.14 contains all of the variables used to estimate the three equations. The three endogenous variables are listed first. They are defined as number of bad days experienced during the past month. So, for example, BadPhysicalHealthDays ranges from 0 to 30, with a mean of 9.88 bad physical health days the past month. The variables BadMentalHealthDays and BadRest/SleepDays pertain to bad mental health days and days without enough rest or sleep.

Overall, this three equation model has a system weighted R-Square of 0.28. In other words, the three equations explained 28% of the variance in the three endogenous variables. Table 3.15 presents the results for the first equation of the model. In the equation, the dependent variable is number of mental health days not good. The equation contains two endogenous variables: number of physical health days not good and number of days without enough rest or sleep. The latter variable is quite significant and has the expected sign – as the number of days without enough rest or sleep increases, so do the number of bad mental health days. The former also has the expected sign but is not significant below the 0.10 level. [43]

[42] 3SLS was used because it is assumed that the error terms in the three equations are correlated (see Theil 1971). The equations were estimated using SAS Version 9.2 for Windows. It should also be noted that all endogenous variables cannot be specified in all of the equations, else the model would be over specified. A stepwise function was not available. Thus, several runs were made to settle on the final specification of the model reported here.

[43] Variable significances are found in the last column of this table. The number communicates the confidence one can have that the variable itself is correlated with the dependent variable. Generally, as a rule-of-thumb, most social scientists will have confidence that a statistically significant correlation exists if the significance value is <0.05, meaning that there is a less than 5% chance that the correlations does not exist. For exploratory research such as described in this section, this requirement is sometimes set at <0.10.

Table 3.14. Endogenous and Exogenous Variables

Variable	Definition	Mean	Min	Max
Endogenous Variables				
BadPhysicalHealthDays	Number of days physical health last month (0-30)	9.88	0	30.0
BadMentalHealthDays	Number of days mental health not good last month (0-30)	7.34	0	30.0
BadRest/SleepDays	Number of days did not get enough rest or sleep last month (0-30)	10.9	0	30.0
Exogenous Variables				
MildewSmell	Frequent mildew odor or musty smell (1=yes, 0=no)	0.24	0	1.0
EnergyBills	How hard is it to pay your energy bills (1= very hard, 5= not at all hard)	2.38	1.0	5.0
EnergyOverFood	How often not purchased food to pay energy bills past year (1= every month, 3= every few months, 6= never)	5.16	1.0	6.0
Headaches	Worse headaches than before over past month (1=yes, 0=no)	0.18	0	1.0
RespiratoryIllnessHousehold	Sum of reported instances of six different respiratory illnesses suffered by one or more household members past year	1.24	0	5.0
Married	Marital status of respondent (1=married, 0-=other)	0.32	0	1.0
RegionHot	Home is located in Hot Humid or Dry Climate Zone (1=Yes, 0=no)	0.10	0	1.0
Smoking	How often respondent currently smokes (1=everyday, 3=not at all)	2.52	1.0	3.0
IndoorTempWinter	Indoor air temperature during winter (1=very cold, 5=very hot)	2.65	1.0	5.0
PrescriptionsOverEnergy	How frequently didn't pay energy bills to purchase prescriptions (1= every month, 3= every few months, 6= never)	5.76	1.0	6.0
WithoutFood	Household member went without food (past 4 weeks) (1=yes, 0=no)	.069	0	1.0
BudgetPlan	Household is on a utility budget plan (1=yes, 0=no)	0.38	0	1.0
CannotAffordPrescription	Household member needed prescription medicines but couldn't afford (1= yes, 0= no)	0.28	0	1.0
CarTitleLoan	Used car title loan to assist paying energy bill (1=yes, 0=no)	0.018	0	1.0
PawnShop	Used pawn shop to assist paying energy bill (1=yes, 0=no)	0.067	0	1.0
PostWxComparison1	Household falls into the post-weatherization comparison 1 group (1=yes, 0=no)	0.46	0	1.0
CannotSeeDoctor	Needed to see doctor but could not because of cost (1=yes, 0=no)	0.29	0	1.0
DisconnectNotice	How often received disconnect, shut-off, or non-delivery notice (1= almost every month, 4=never)	3.39	1.0	4.0
MoldInHome	Have seen mold in home (1=yes, 0=no)	0.24	0	1.0
HomeDrafty	How often home too drafty (1= all the time, 4=never)	3.13	1.0	4.0
WindowsOpenSummer	How often windows open in summer (1=never, 5 = all the time)	3.16	1.0	5.0
AgeRespondent	Age of respondent	57.7	18.0	95.0
ChildrenInHousehold	Number of children in household	0.68	0	8.0
Male	Gender of respondent (1=male, 0 = female)	0.26	0	1.0
DirtyAirFilter	Home probably has dirty air filter (1=yes, 0=no)	0.25	0	1.0

One can hypothesize that worries about issues related to energy can negatively influence mental health. Several exogenous variables in the model support this broad hypothesis. For example, respondent mental health degrades as households find it more difficult to pay energy bills (see variable EnergyBills) and not purchase food to pay energy bills (see variable EnergyOverFood). Respondents who need to pawn personal possessions to pay energy bills also suffer more bad mental health days. Conversely, households that are on utility bill payment plans appear to have fewer worries about energy bills and experience fewer bad mental health days.

One can also hypothesize that conditions inside the home could impact mental health. Two results support this hypothesis. Respondents whose homes are frequently cold in the winter and report frequent mildew odor or musty smells in their homes also report more bad mental health days.

The model includes a couple of statistically significant demographic variables. The 'married' variable is significant and the sign of its coefficient suggests that married respondents report fewer bad mental health days. The other variable is Smoking and describes how much the respondent smokes. The sign of this variable is negative. Given how this variable is measured (1= smokes a lot, 3= never smokes), this suggests that people who smoke less have fewer bad mental health days.

Lastly, a statistically significant variable has a counter-intuitive sign: the control group. This result suggests that if the home had been previously weatherized, respondents report more bad mental health days. Since the model also includes several other variables that were positively influenced by weatherization (e.g.,, ability to pay bills, the home is more comfortable), one can argue that in this case this variable is capturing the residual impacts of other aspects of the respondents' lives that impact mental health.

The next equation to be addressed is number of days did not get enough rest or sleep (see Table 3.16). Similar to the mental health model, one endogenous variable is quite significant (number of bad mental health days) and the other is close to being significant (number of bad physical health days). Both coefficients carry the expected sign.

Two exogenous variables address home comfort: IndoorTempWinter and HomeDrafty. The former relates to indoor air temperatures during winter. The sign of the coefficient of this significant variable, again given the definition of the variable, indicates that respondents get more rest and sleep as their house is warmer. The latter, relating to home draftiness, is not highly significant but suggests that less drafty homes are more conducive to good rest and sleep.

Table 3.15. Equation 1: Dependent Variable – BadMentalHealthDays

Independent Variables	DF	Parameter Estimate	Standard Error	p value
Intercept	1	-2.43320	4.242016	0.5663
BadPhysicalHealthDays	1	0.152041	0.104105	0.1444
BadRest/SleepDays	1	0.615362	0.159753	0.0001
MildewSmell	1	1.006326	0.547007	0.0660
EnergyBills	1	-0.51351	0.259414	0.0479
EnergyOverFood	1	-0.34890	0.167070	0.0369
Headaches	1	1.951413	1.319693	0.1394
RespiratoryIllnessHousehold	1	-0.04219	0.377992	0.9111
Married	1	-1.00737	0.451982	0.0260
RegionHot	1	-0.90116	0.705231	0.2015
PostWxComparison1	1	1.002752	0.440932	0.0231
Smoking	1	-0.75768	0.381206	0.0470
IndoorTempWinter	1	1.410524	0.504619	0.0053
PrescriptiionsOverEnergy	1	0.362970	0.276206	0.1890
WithoutFood	1	0.548719	1.447514	0.7047
BudgetPlan	1	-1.00440	0.521878	0.0545
CannotAffordPrescription	1	0.852383	0.724312	0.2395
CarTitleLoan	1	-2.23629	1.573159	0.1554
PawnShop	1	2.730431	1.081842	0.0117

One can hypothesize that worries can not only impact mental health but also rest and sleep. Generally, the variables included in this model support this hypothesis, though only one is statistically significant at the 0.10 level – WithoutFood, household member went without food (past 4 weeks). Older respondents reported getting better rest and sleep. Respondents living in homes with a higher incidence of respiratory problems reported having more bad days of rest and sleep.

Table 3.16. Equation 2 – Dependent Variable BadRest/SleepDays

Variable	DF	Parameter Estimate	Standard Error	p value
Intercept	1	13.82188	1.846240	<.0001
Headaches	1	1.220883	0.856709	0.1543
RespiratoryIllnessHousehold	1	0.531829	0.244954	0.0301
IndoorTempWinter	1	-0.98377	0.386553	0.0110
WithoutFood	1	1.893109	1.110941	0.0886
BudgetPlan	1	0.632055	0.433061	0.1446
CannotSeeDoctor	1	0.566555	0.466184	0.2244
DisconnectNotice	1	-0.32085	0.211799	0.1300
MoldInHome	1	0.497823	0.492523	0.3123
HomeDrafty	1	-0.43501	0.307160	0.1569
WindowsOpenSummer	1	0.204898	0.166647	0.2191
PawnShop	1	-2.36567	0.897746	0.0085
BadPhysicalHealthDays	1	0.185683	0.136138	0.1728
AgeRespondent	1	-0.09103	0.025466	0.0004
BadMentalHealthDays	1	0.495236	0.118810	<.0001

The last equation pertains to number of days that the respondent's physical health is not good (Table 3.17). The results for this equation indicate that bad rest and sleep is positively correlated with bad physical health days. Also, as might be expected, a higher incidence of respiratory problems in homes leads to more bad physical health days. However, keeping the windows open more often in summer seems to reduce the number of bad health days. Unlike rest and sleep, age is positively correlated with this dependent variable. Being male is also positively correlated with bad sleep days. The most telling result in this equation is found with respect to variable CannotAffordPrescription: household member needed prescription medicines but could not afford. Since we saw in Section 3.1 that weatherization is associated with a better ability to afford prescription medicines, it can be inferred that weatherization can indirectly improve physical health through this variable. The control group variable, in this case, directly indicates that weatherization reduces the number of bad physical health days experienced by respondents.

Table 3.17. Equation 3 – Dependent Variable BadPhysicalHealthDays

Variable	DF	Parameter Estimate	Standard Error	P value
Intercept	1	-6.15277	3.123759	0.0491
Headaches	1	1.271204	1.113459	0.2538
RespiratoryIllnessHousehold	1	0.632814	0.308666	0.0405
PostWxComparison1	1	-0.52150	0.521254	0.3172
WithoutFood	1	0.448330	1.396364	0.7482
MoldInHome	1	-1.11778	0.698830	0.1099
HomeDrafty	1	-0.48934	0.397050	0.2180
ChildrenInHousehold	1	-0.39714	0.238968	0.0967
WindowsOpenSummer	1	-0.58567	0.215852	0.0067
AgeRespondent	1	0.188221	0.025329	<.0001
BadRest/SleepDays	1	0.674933	0.152998	<.0001
Male	1	1.159930	0.558920	0.0381
DirtyAirFilter	1	-0.65401	0.559562	0.2427
CannotAffordPrescription	1	1.750451	0.659347	0.0080

In summary, the simultaneous equation model suggests that there is a complicated relationship between weatherization and general descriptors of human health and the quality of life. The results suggest that variables that weatherization impacts, such as the ability to pay bills and the comfort of one's home can, in turn, positively impact mental and physical health and the ability to get good rest and sleep.

The three specified equations shown above were estimated for the pre-weatherization treatment group and for the post-weatherization comparison group 1. The equations were simultaneously solved using variable means for pre-weatherization and post-weatherization to calculate bad mental health days, days without enough sleep and rest, and bad physical health days for both groups. Given all of the various impacts of weatherization on the exogenous variables, this analysis indicates that weatherization reduces the number of bad mental health days per month by 6, the number of days without enough sleep or rest by 4, and the number of bad physical health days by 3.

3.4 ASTHMA CORRELATIONS AND LOGISTIC REGRESSION MODEL RESULTS

This section provides additional statistical analysis to further explore the impact of weatherization on asthma symptoms and treatment beyond the descriptive frequencies reported in the previous section. Correlations were analyzed and logistic regression models were built to determine the role of weatherization in reducing exposure to environmental asthma triggers thereby reducing ED visits and hospitalizations.

Relationships between individual variables pertaining to the characteristics of the survey respondents and the home environment with asthma-related ED visits and hospitalizations were examined with Pearson's correlation coefficient.[44] Relationships were judged by the coefficient of determination (R^2) and the relationship's statistical significance (p-value). The coefficient of determination (R^2) is the proportion of

[44] Variables included were either dichotomous or dummy variables.

total variability in ED visits or hospitalization cases accounted for by another variable (i.e. cooking stove fuel). The p-value, or observed significance level, represents the probability of finding the observed relationship within this WAP asthma sample even if no such relationship exists at the population level. Relationships are reported at the .05 and .01 significance levels.

Tables 3.18 and 3.19 present high-level categories containing variables tested for statistical significance and their associated coefficients of determination (R^2). Table 3.18 reveals categories with variables correlating at the .05, .01 or .001 significance levels and their associated R^2 values in a *pre-weatherized* home environment (treatment group) and Table 3.19 reveals correlating values in a *post-weatherized* home environment (comparison group[45]). It is important to note again that the pre- and post-weatherization environments are not directly comparable because the treatment and comparison group samples were derived from two different sets of households. The whole asthma treatment and comparison groups were used to best represent the pre- and post-weatherization environments because they had the largest sample sizes.

Based on the results presented it is clear and not surprising that ED visits and hospitalization from asthma are positively and highly correlated with each other (pre-weatherization: $R^2 = .616$, $p < .01$; post-weatherization: $R^2 = .505$, $p < .01$) and a strong correlation was found between those that reported use of the ED in the comparison group post-weatherization (1 year post-wx) and those reporting use of the ED in the second phase of the survey (2 years post-wx) suggesting that those with the most chronic symptoms or uncontrolled asthma were those persons frequently using the ED and those requiring hospitalization after being admitted to the ED. Variables that correlated with urgent care in the pre-weatherization home environment were not always correlated in the post-weatherization environment. Variables falling under the “home energy insecure” and “food insecure” categories correlated with urgent care use due to asthma in the pre-weatherized treatment sample, but not in the post-weatherized comparison sample. Other variables behaving this way include “use of secondary heat from built in gas, oil, or kerosene room heaters” and “wood is main heating fuel.” Interestingly, mechanical ventilation positively correlates with hospitalization. The majority of the treatment group sample (65%) reported having working mechanical ventilation in either the bathroom or kitchen.

Many correlating variables in the post-weatherization but not in the pre-weatherization environment are those typically outside the scope of weatherization; not working due to disability, prescription affordability, and main heating equipment and fuel type. However, a few variables hypothesized to be mitigated by weatherization correlated with urgent care within this sample; use of secondary heat (in general), use of cooking stove for heat, infestations of cockroaches and other insects, and home kept at an unsafe or unhealthy temperature. Again, the pre- and post-weatherization environments captured in this analysis are not directly comparable and the pre-weatherized home environment of the comparison group is unknown. For this reason, the logistic regression analysis was conducted using the treatment group pre- and post-weatherization environments to explore the impact of weatherization within the same treatment group.

[45] The comparison group was selected for the “post-weatherized” environment for correlations due to its larger sample size compared to the treatment group.

Table 3.18. Correlating Factors within a Pre-Weatherized Home Environment (Treatment Group)

Pre-Weatherization (Treatment Group) Statistically Significant Correlating Factors		**ED Visit-Asthma**	**Hospitalization-Asthma**
Black/African American (n=93)	Nature of the Relationship		+
	Coefficient of Determination (R^2)		.267**
Shortness of breath (n=92)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.307**	.269**
Bronchitis (n=91)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.262*	
Prescription Affordability[46] (n=93)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.372***	.233*
Prescription Affordability[47] (n=93)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.207*	
Home Energy Insecure[48] (n=93)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.246*	
Food Insecure[49] (n=92)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.220*	.235*
Main heating fuel is wood (n=91)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.206*	
Used secondary heat from built-in room heater; gas/oil/kerosene (n=38)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.422**	.380*
Mechanical ventilation (n=93)	Nature of the Relationship		+
	Coefficient of Determination (R^2)		.227*
Frequency of Symptoms[50] (n=92)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.303**	.237*
High-cost asthma patient (n=92)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.220*	.250*
Had to stay overnight in the hospital because of asthma (n=93)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.616***	

[46] Survey Question: *How frequently didn't pay energy bills to purchase prescriptions?*
Range of responses: 1=EveryMonth; 2=EveryOtherMonth; 3=EveryFewMonths; 4=EverySixMonths; 5=Every12Months; 6=Never

[47] Survey Question: *How often didn't fill prescription/took less than amount prescribed to pay utility bill?*
Range of responses: 1=EveryMonth; 2=EveryOtherMonth; 3=EveryFewMonths; 4=EverySixMonths; 5=Every12Months; 6=Never

[48] Electricity, Natural Gas, Fuel Oil, Propane or Kerosene ran out (1=Yes; 2=No)

[49] *Worried household members wouldn't have nutritious food (in past 4 weeks)* (1=Yes; 2=No)

[50] Range of Frequency of Asthma Symptoms: (1=never; 2= <1DayAgo; 3=1-6DaysAgo; 4=1Week- <3MonthsAgo; 5=3Months-<1YearAgo; 6=1Year-<3YearsAgo; 7=3-5YearsAgo; 8=>5YearsAgo)

Went to ED because of asthma (n=93)	Nature of the Relationship		+
	Coefficient of Determination (R^2)		.616***
Home Energy Insecure[51] (n=93)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.387***	.225*

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

[51] Used Pawn shop to assist paying energy bill (1=Yes; 2=No)

Table 3.19. Correlating Factors within a Post-Weatherized Home Environment (Comparison Group)

Post-Weatherization 1-Year (Comparison Group) Statistically Significant Correlating Factors		ED Visit-Asthma	Hospitalization-Asthma
Shortness of breath (n=123)	Nature of the Relationship		+
	Coefficient of Determination (R^2)		.206*
Persistent Cold Symptoms (n=121)	Nature of the Relationship		+
	Coefficient of Determination (R^2)		.236**
Prescription Affordability[52] (n=122)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.323***	
Not working due to disability[53] (n=123)	Nature of the Relationship		+
	Coefficient of Determination (R^2)		.181*
Hot Climate Zone (Hot-humid or Hot-dry) (n=122)	Nature of the Relationship	-	
	Coefficient of Determination (R^2)	.238**	
Main Heating equipment is heat pump (n=120)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.322***	.416***
Main heating fuel is electricity (n=122)	Nature of the Relationship	+	+
	Coefficient of Determination (R^2)	.263**	.194*
Used secondary heat in general (n=120)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.198*	
Use of fireplace for secondary heat (n=122)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.181*	
Use of cooking stove for secondary heat (n=122)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.194*	
Kept home at unsafe/unhealthy temperature[54] (n=120)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.207*	
Infestations of cockroaches and other insects[55] (n=121)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.350***	
Had to stay overnight in the hospital because of asthma Post-Wx 1-Year (n=122)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.505***	
Went to ED because of asthma Post-Wx 1-Year (n=122)	Nature of the Relationship		+
	Coefficient of Determination (R^2)		.505***

[52] Household member needed prescriptions but couldn't afford (1=Yes; 2=No)
[53] Survey Question: *Does a physical, mental, or emotional problem now keep you from working a job?* (1=Yes; 2=No)
[54] Survey Question: *How often kept home at unsafe or unhealthy temperature?*
Range of responses: 1=AlmostEveryMonth; 2=SomeMonth; 3=1-2Months; 4=Never
[55] Home is *somewhat, very or extremely infested with cockroaches or other insects* (1=Yes; 2=No)

Had to stay overnight in the hospital because of asthma Post-wx 2-Years (n=55)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.302*	
Went to ED because of asthma Post-Wx 2-Years (n=56)	Nature of the Relationship	+	
	Coefficient of Determination (R^2)	.431***	

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

The correlation results presented in Table 3.18 and 3.19 suggest that the constellation of conditions in homes pertinent to asthma are different pre- and post-weatherization. In addition we should also ask whether the treatment and comparison groups are different from each other with respect to asthma analyses and whether the whole asthma and paired samples also differ from one another. If so, then it could be argued that assessments of the impacts of weatherization upon asthma-related symptoms and events should be limited only to comparisons within the treatment group pre- and post-weatherization, and further to the whole asthma treatment sample because of the small number of households in the paired sample.

The whole asthma sample treatment and comparison groups were compared across numerous variables (see Tables 3.20 to 3.24 and A.1 to A.7 in Appendix A). Assessing the degree to which the samples diverge was considered when selecting the sample and group for the monetization of the benefits associated with reductions in asthma symptoms because deviations in characteristics may influence variation in frequency or severity of asthma symptoms between the two samples. Using descriptive frequencies and cross-tabulations, categories where the samples diverge were developed (Figure 3.5). Although statistical tests were not conducted, one can make the case that the whole asthma sample treatment and comparison groups vary to the degree that only comparisons made within the treatment group pre- and post-weatherization should be made based on the following reasons:

- The groups are different with respect to key demographics (e.g.,, 23% of treatment group households are elderly versus 31% of comparison group households);

- A higher percentage of treatment group households live in the cold climate zone, in towns and in mobile homes versus comparison group households living in moderate and hot-humid climate zones, rural areas, and single family detached homes;

- Treatment group homes are heated more frequently with portable heaters and fireplaces as the main heat source, but the comparison group in the same household sample had a high percentage (13%) reporting use of portable kerosene heaters versus the treatment group with no households reporting use of the heaters; and

- Treatment group homes have a much higher rate (by about 10%) of installed mechanical ventilation post-weatherization than the comparison group homes (the rate of installation for the comparison group homes post-weatherization is approximately equal to the rate of the treatment homes pre-weatherization, making it quite difficult to address ventilation in any analyses involving the comparison group homes)

Changes in dwelling quality were explored between the treatment and comparison groups and between each of the samples (Tables 3.20 to 3.24). Comparison group households in the asthma samples tended to experience thermal stress post-weatherization compared to the treatment group sample post-weatherization (Table 3.20). Comparison group households across all samples reported higher incidence of the home being “drafty all or most of the time” and having “seen mold” or observed a “frequent mildew/musty odor” post-weatherization compared to the treatment group samples post-weatherization (Table 3.21 and 3.22). Interestingly, an increase in home infestations of cockroaches and other insects was observed in the comparison group households across all samples approximately 2 years post-weatherization (Table 3.23).

Table 3.20. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample by Exposure to Thermal Stress Pre- and Post-Wx

% of Respondents Reporting ***Home is very hot in the summer*** **by Group and by Sample**	**Home Very Hot in Summer**	**Difference**
Whole Sample-Treatment Group (**Pre-Wx**; n=659)	11.8%	(-)7.8%
Whole Sample-Treatment Group(**Post-Wx** 1-year; n=396)	4.0%	
Whole Sample-Comparison Group (**Post-Wx** 1-Year; n=797)	4.9%	(-)0.4%
Whole Sample-Comparison Group(**Post-Wx** 2-years; n=424)	4.5%	
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=93)	14.0%	(-)10.4%
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=55)	3.6%	
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year; n=122)	8.2%	(-)3.4%
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years; n=63)	4.8%	
Asthma Paired Sample-Treatment Group (**Pre-Wx**; n=40)	7.5%	(-)2.5%
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year; n=41)	5.0%	
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year; n=52)	7.7%	(-)1.7%
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years; n=52)	6.0%	

Table 3.21. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample by Draftiness of the Home Pre- and Post-Wx

% of Respondents Reporting Home is ***Drafty Most or All of the time*** **by Group and by Sample**	**Drafty**	**Difference**
Whole Sample-Treatment Group (**Pre-Wx**; n=657)	29.5%	(-)23.6%
Whole Sample-Treatment Group(**Post-Wx** 1-year; n=393)	5.9%	
Whole Sample-Comparison Group (**Post-Wx** 1-year; n=799)	8.9%	(-)4.0%
Whole Sample-Comparison Group(**Post-Wx** 2-years; n=427)	4.9%	
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=93)	40.9%	(-)33.8%
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=56)	7.1%	
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year; n=123)	12.2%	(-)1.4%
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years; n=65)	10.8%	
Asthma Paired Sample-Treatment Group (**Pre-Wx**; n=42)	40.5%	(-)33.4%
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year; n=42)	7.1%	
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year; n=53)	13.2%	(-)1.9%
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years; n=53)	11.3%	

Table 3.22. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample by Mold/Mildew Pre- and Post-Wx

% of Respondents Reporting Have ***seen mold*** **and/or home has** ***frequent mildew/musty odor*** **by Group and by Sample**	**Mold, Mildew or Musty**	**Difference**
Whole Sample-Treatment Group (**Pre-Wx**; n=657)	42.5%	(-)13.1%
Whole Sample-Treatment Group(**Post-Wx** 1-year; n=398)	29.4%	
Whole Sample-Comparison Group (**Post-Wx** 1-year; n=798)	27.2%	(-)0.7%
Whole Sample-Comparison Group(**Post-Wx** 2-years; n=429)	26.5%	
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=92)	51.1%	(-)25.6%
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=55)	25.5%	
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year; n=123)	31.7%	(-)5.5%
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years; n=65)	26.2%	
Asthma Paired Sample-Treatment Group (**Pre-Wx**; n=40)	50.0%	(-)22.5%
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year; n=40)	27.5%	
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year; n=52)	32.7%	(-)1.9%
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years; n=52)	30.8%	

Table 3.23. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample by Infestation of Insects of the Home Pre- and Post-Wx

% of Respondents Reporting Home is *Somewhat, Very,* or *Extremely* infested with *cockroaches/insects* by Group and by Sample	**Infested**	**Difference**
Whole Sample-Treatment Group (**Pre-Wx**; n=661)	25.3%	(-)10.7%
Whole Sample-Treatment Group(**Post-Wx** 1-year; n=398)	14.6%	
Whole Sample-Comparison Group (**Post-Wx** 1-year; n=801)	16.2%	(+)1.3%
Whole Sample-Comparison Group(**Post-Wx** 2-years; n=429)	17.5%	
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=92)	25.0%	(-)12.5%
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=56)	12.5%	
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year; n=122)	17.2%	(+)1.6%
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years; n=64)	18.8%	
Asthma Paired Sample-Treatment Group (**Pre-Wx**; n=40)	25.0%	(-)10.4%
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year; n=41)	14.6%	
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year; n=52)	11.5%	(+)8.1%
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years; n=51)	19.6%	

Households of low SES tend to be more energy insecure as a greater portion of their income is used for home heating and cooling. Prior to weatherization these households may also use supplemental or secondary sources for heat if main sources of heat are shut-off or if the home is poorly sealed or insulated. One of these supplemental heat sources used is a cooking oven. Using a cooking oven for heat not only is a safety hazard for burns and fire, but it could also expose vulnerable occupants to particulate matter and fumes. The percentage of households in all sample comparison groups who "used the oven to heat the house" was higher post-weatherization than the treatment group households post-weatherization (Table 3.24).

Table 3.24. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample by Use of Oven for Heat Pre- and Post-Wx

% of Respondents Reporting Have *used the oven to heat the house* by Group and by Sample	**Oven for heat**	**Difference**
Whole Sample-Treatment Group (**Pre-Wx**; n=659)	22.8%	(-)9.5
Whole Sample-Treatment Group(**Post-Wx** 1-year; n=398)	13.3%	
Whole Sample-Comparison Group (**Post-Wx** 1-year; n=797)	16.2%	(-)1.8%
Whole Sample-Comparison Group(**Post-Wx** 2-years; n=430)	14.4%	
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=93)	22.6%	(-)4.7%
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=56)	17.9%	
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year; n=123)	21.1%	(+)0.4%
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years; n=65)	21.5%	
Asthma Paired Sample-Treatment Group (**Pre-Wx**; n=41)	17.1%	0.0%
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year; n=41)	17.1%	
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year; n=52)	25.0%	(-)5.9%
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years; n=52)	19.1%	

Cross-tabulations were completed to explore the role of gender and race on asthma related urgent care pre- and post-weatherization (Table 3.25). This analysis suggests that both females and males in the treatment group experienced a reduction in use of the ED post-weatherization with nearly 16% of females reporting at least one visit to the ED in the 12 months prior to weatherization vs 3% post-weatherization. Male respondents reported a reduction of nearly 8%. However in the comparison group sample, 22% of females and 10% of males reported use of the ED post-weatherization. No males in the paired asthma sample reported use of the ED in either phase of the survey and no males in the any group reported hospitalization from asthma post-weatherization (Table 3.26). Similarly, none of the African Americans in the treatment group sample reported use of the ED post-weatherization versus an increase in use post-weatherization (from year 1 to year 2) in the comparison group (Table 3.27) and the percentage of African Americans that reported hospitalizations related to asthma in the asthma paired sample (16.7%) is approximately half of what is reported by the this demographic in the whole asthma sample (33.3%) (Table 3.28). These divergent patterns suggest an insufficient number of African Americans in the asthma survey sample to be able to determine the impact of weatherization on this population specifically.

Table 3.25. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample for Emergency Department (ED) Visits by Gender

% of Respondents Reporting Visit to ED due to asthma by Group and by Sample and by Gender	**ALL**	**Female**	**Male**
Whole Asthma Sample-Treatment Group (**Pre-Wx**)	16.0% (n=93)	15.9% (n=69)	16.7% (n=24)
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year)	6.6% (n=47)	2.8% (n=36)	9.1% (n=11)
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year)	18.9% (n=122)	21.5% (n=93)	10.3% (n=29)
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years)	16.1% (n=56)	19.1% (n=47)	0.0% (n=9)
Asthma Paired Sample-Treatment Group (**Pre-Wx**)	7.3% (n=41)	6.7% (n=30)	9.1% (n=11)
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year)	4.9% (n=41)	3.3% (n=30)	9.1% (n=11)
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year)	19.2% (n=52)	22.7% (n=44)	0.0% (n=8)
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years)	17.3% (n=52)	20.5% (n=44)	0.0% (n=8)

Table 3.26. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample for Hospitalizations by Gender

% of Respondents Reporting Hospitalization due to asthma by Group and by Sample and by Gender	**ALL**	**Female**	**Male**
Whole Asthma Sample-Treatment Group (**Pre-Wx**)	12.8% (n=93)	10.1% (n=69)	20.8% (n=24)
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year)	9.8% (n=47)	13.9% (n=36)	0.0% (n=11)
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year)	7.2% (n=122)	7.4% (n=94)	6.9% (n=29)
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years)	5.5% (n=56)	6.5% (n=46)	0.0% (n=9)
Asthma Paired Sample-Treatment Group (**Pre-Wx**)	12.2% (n=41)	6.7% (n=30)	27.3% (n=11)
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year)	9.8% (n=41)	13.3% (n=30)	0.0% (n=11)
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year)	5.8% (n=52)	6.8% (n=44)	0.0% (n=8)
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years)	5.9% (n=52)	7.0% (n=44)	0.0% (n=8)

Table 3.27. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample for ED Visits by African American/Non-African American

% of Heads of Respondents Reporting Visit to ED due to asthma by Group and by Sample and by Black/African American	**ALL**	**Black/ African American**	**Not Mentioned**
Whole Asthma Sample-Treatment Group (**Pre-Wx**)	16.0% (n=93)	26.7% (n=15)	14.1% (n=78)
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year)	6.6% (n=47)	0.0% (n=7)	5.0% (n=40)
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year)	18.9% (n=122)	27.8% (n=18)	17.3% (n=104)
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years)	16.1% (n=56)	44.4% (n=9)	10.6% (n=47)
Asthma Paired Sample-Treatment Group (**Pre-Wx**)	7.3% (n=41)	0.0% (n=6)	8.6% (n=35)
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year)	4.9% (n=41)	0.0% (n=6)	5.7% (n=35)
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year)	19.2% (n=52)	37.5% (n=8)	15.9% (n=44)
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years)	17.3% (n=52)	44.4% (n=9)	11.6% (n=43)

Table 3.28. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Paired Sample for Hospitalizations by Demographic

% of Respondents Reporting Hospitalization due to asthma by Group and by Sample and by Demographic	**ALL**	**Black/ African American**	**Not Mentioned**
Whole Asthma Sample-Treatment Group (**Pre-Wx**)	12.8% (n=93)	33.3% (n=15)	9.0% (n=78)
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year)	9.8% (n=47)	14.3% (n=7)	10.0% (n=40)
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year)	7.2% (n=123)	5.6% (n=18)	7.6% (n=105)
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years)	5.5% (n=55)	22.2% (n=9)	2.2% (n=46)
Asthma Paired Sample-Treatment Group (**Pre-Wx**)	12.2% (n=41)	16.7% (n=6)	11.4% (n=35)
Asthma Paired Sample-Treatment Group (**Post-Wx** 1-year)	9.8% (n=41)	16.7% (n=6)	8.6% (n=35)
Asthma Paired Sample-Comparison Group (**Post-Wx** 1-year)	5.8% (n=52)	12.5% (n=8)	4.5% (n=44)
Asthma Paired Sample-Comparison Group (**Post-Wx** 2-years)	5.9% (n=51)	22.2% (n=9)	2.4% (n=42)

It is for these reasons that the balance of the asthma-related analyses and monetization focus on the whole asthma sample treatment group pre- and post-weatherization (Figures 3.3 and 3.4).

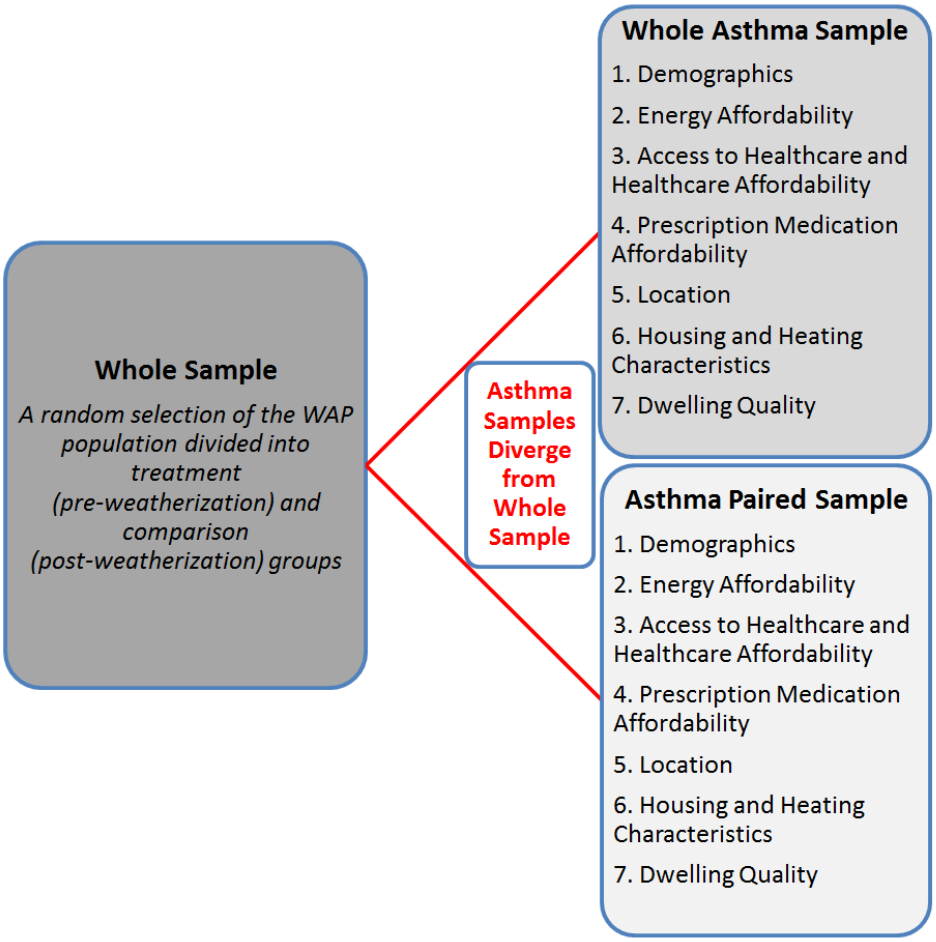


Figure 3.3. Categories for Sample Deviation

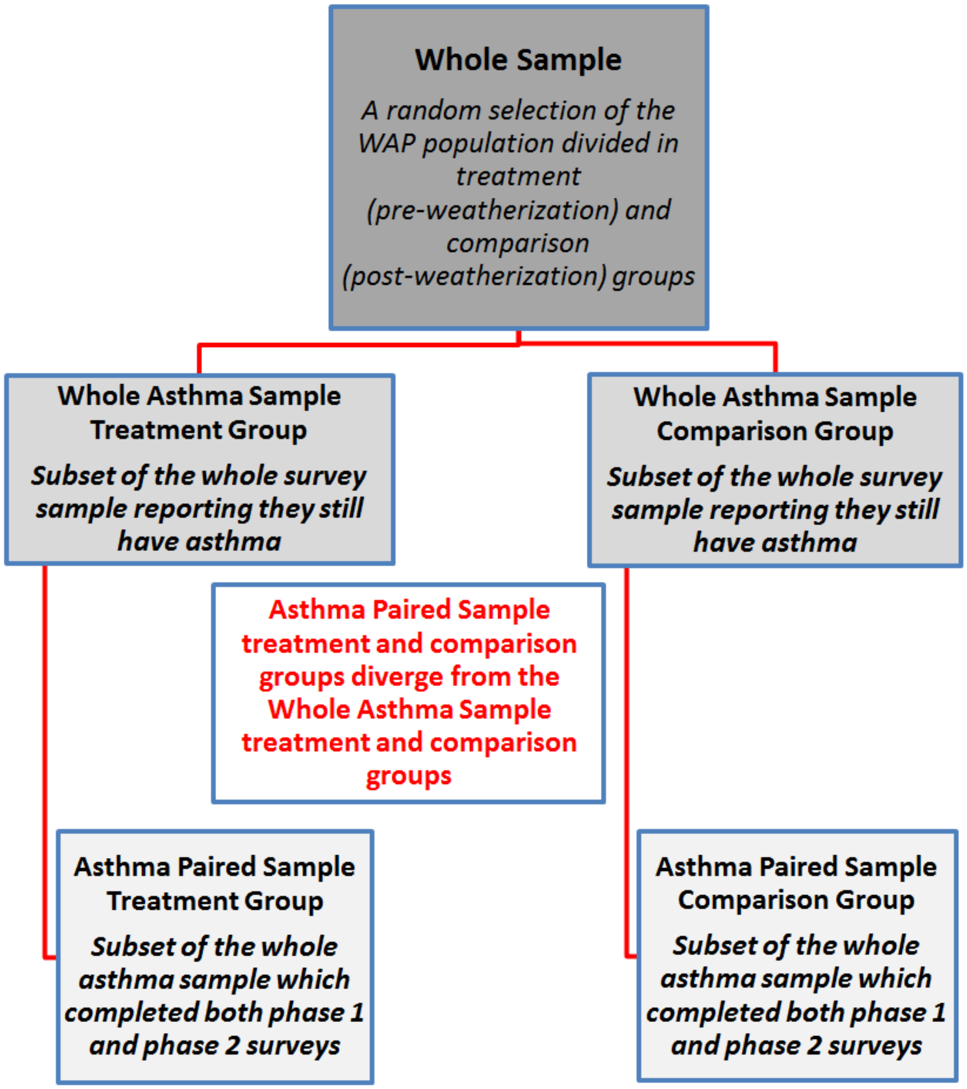


Figure 3.4. Selection of Whole Asthma Sample Treatment Group for Monetization of Benefits Related to Asthma

Presented next are the results from a binary logistic regression analysis using this sample. The dependent variable is whether the respondent visited the emergency department because of asthma at least once during the previous twelve months (0=yes, 1=no). As described below, one of the independent variables was whether the home the respondent was living in had or had not been weatherized at the time the survey question was asked. The correlations previously described were used to determine relationships between additional individual independent variables (e.g.,, secondary heat sources) and urgent care in both pre-weatherization and post-weatherization samples. After controlling for other predicting factors generally considered beyond the scope of WAP, the model suggests that weatheration predicts the use of ED visits due to asthma in 1/3 of cases where visits to ED were actually observed (Table 3.29). The inverse relationship suggests that persons with asthma living in homes weatherized through WAP are less likely to visit the ED from asthma.

Table 3.29. Logistic Regression Analysis; Predicting ED visits due to Asthma

Logistic Regression Analysis
Dependent Variable = ED Visits (discrete values; no=0, yes=1)[A]

Omnibus Tests of Model Coefficients[B]		
Chi-square[C]	Degrees of Freedom (df)	Sig.
25.124	11	.009**

Model Summary- Pseudo-R^2 Statistics[D]	
Cox & Snell R Square[E]	Nagelkerke R Square[F]
.176	.344

Hosmer and Lemeshow Test[G]		
Chi-square	df	Sig
3.282	8	.915

Percent Correct Predictions[H]				
		Predicted		
		Visited ED due to Asthma		
Observed		No	Yes	% Correct
Visited ED due to Asthma	No	114	1	99.1
	Yes	10	5	33.3
Overall %				91.5

Variables in the Equation[I]						
Variables in the Equation	B	S.E.	t-value	Sig.	Exp(B)	1/Exp(B)[56]
Weatherized (0=No, 1=Yes)	**-1.795**	**.850**	**-2.11**	**.035***	**.166**	**6.02**
Black/African American (0=No, 1=Yes)	-1.575	1.089	-1.45	.148	.207	4.83
City Location (0=No, 1=Yes)	1.492	.844	1.77	.077	4.444	
Smoking allowed inside the home (0=No, 1=Yes)	-1.567	.861	-1.82	.069	.209	4.78
Chronic respiratory problems[57] (0=No, 1=Yes to one of the three problems, 2=Yes to two of the problems, 3=Yes to all three problems)	1.247	.484	2.58	.010**	3.479	
Infestation of cockroaches/insects or mice/rodents (0=No, 1=Yes to one of the two infestation types, 2=Yes to both infestation types of)	.871	.535	1.63	.104	2.390	
Not working due to disability (0=No, 1=Yes)	.702	.747	.94	.347	2.018	

[56] Odds ratio
[57] Chronic respiratory problems include shortness of breath from light work or exercise, respiratory allergy, or bronchitis

Healthcare Coverage (0=No, 1=Yes)	-1.535	.928	-1.65	.098	.215	4.65
Electricity is main heating fuel (0=No, 1=Yes)	1.186	.736	1.61	.107	3.272	
Cooking stove is Natural Gas (0=No, 1=Yes)	1.598	.838	1.91	.056	4.944	
Worried HHLD members would not have nutritious food (0=No, 1=Yes)	1.163	.703	1.65	.022	5.017	

A. Dependent variable is a discrete categorical variable. The data derives from a counting process instead of a measuring process which is used for continuous variables.
B. The "Omnibus Tests of Model Coefficients" reveals the overall significance of the model upon determining whether or not the model predicts ED visits due to asthma better than chance alone.
C. The chi-sqare statistic provides a comparison of categorical responses between the independent groups in the model. The model is significant at the <.01 level allowing us to reject the null hypothesis that there is no relationship between the variables in the model and ED visits because of asthma
D. Psuedo R-Square statistics offer an approximation of a R-square value used in ordinary least-square regressions. Similar to the R-squared higher values suggests the model fits well upon measuring the proportion of variance accounted for in the dependent variable based on the predicting power of the independent variable(s) in the model.
E. The "Cox & Snell R Square" statistic is a pseudo-R with a maximum value of .75
F. The "Nagelkerke R Square" statistic is a pseudo-R with a maximum value of 1
G. The "Hosmer and Lemeshow Test" measures the model's goodness of fit by comparing observed to expected or predicted frequencies. In this model there is no statistical signifance for any lack of agreement or deviation between the observed and predicted probabilities. The results from this test suggest the model is a good fit.
H. The classification of the model is based on the "Percent Correct Predictions" and is determined by using all the predictors in the model to correctly predict the No and Yes to ED Visit responses. This model (with 11 predictors) correctly classifies 91.5% of cases. However, it only correctly classifes 33.3% of the "Yes" to ED visit cases (n=15).
I. The "Variables in Equation" lists each of the predictors included in the model, their coeficient (B), standard error (S.E.), t-value, statistical significance or p value (Sig.), exponentiated coefficient (Exp (B)),and inverse of the Exp(B) if the coefficient is negative (1/Exp(B)).

The results from the logistic regression model indicate that weatherization is associated with fewer ED visits due to asthma after controlling for the following variables:

- Head of Household Demographics and Characteristics
  - Black/African American
  - Not working due to a disability
- Access to Healthcare
  - Had healthcare coverage in last 12 months
- Health Status
  - Chronic respiratory problem (shortness of breath from light work or exercise, bronchitis or respiratory allergies)
- Location
  - City location
- Building Characteristics
  - Electricity is main heating fuel
  - Cooking stove is natural gas
- Dwelling Quality
  - Home is somewhat, very or extremely infested with cockroaches/insects or mice/rodents
- Psycho-Social Stress (indicator not related to fuel poverty)
  - Food Insecure; Worried household members would not have nutritious food

The overall model is statistically significant at the .01 level according to the chi-square statistic. The negative coefficient indicates that persons residing in homes weatherized by WAP are 6 times less likely to visit the ED due to asthma symptoms after controlling for variables typically beyond the scope of WAP. Although the model predicts all responses 91.5% correctly, it only predicts the observed visits to the ED at 33.3%. Further research is still needed to determine a more precise impact of WAP on ED use by persons with asthma.

4. MONETIZATION OF HEALTH BENEFITS

This section of the report presents results of efforts to monetize some of the health benefits attributable to weatherization. Two approaches were taken to accomplish this task. The first approach, presented in Section 4.1, entailed directly asking clients whose homes were weatherized how their health-related expenses changed post-weatherization. The second approach is more analytical and generally focused not on out-of-pocket expenses experienced by households, but on reductions in expenses that could be deemed to be societal (e.g.,, hospitalization costs paid by insurers), related to ratepayers, or other household financial benefits (e.g.,, the monetary benefits associated with avoided deaths). Eleven health-related non-energy benefits were treated in this analytical fashion and are addressed in Section 4.2.

4.1 MONETARY BENEFITS OF WEATHERIZATION: OCCUPANT SURVEY RESULTS

The second administration of the national occupant survey contained several additional questions pertaining to potential changes in household finances post-weatherization.[58]

Table 4.1 contains results from this question: *How much do you think you save per year in out of pocket costs for doctor's visits and/or medications since having your home weatherized?* This question was asked only if the respondent indicated improved health and attributed some of their improved health to weatherization (See Table 3.3). The mean of the savings is $572 per year for the post-weatherization treatment group and $462 for the post-weatherization comparison group. These results appear to be strongly influenced by a small number of households that experienced very significant savings. Spreading the post-weatherization treatment group savings over the entire population of homes weatherized in PY 2008 yields an average first year savings per unit of $93 and for all units a savings of $9.1M.[59]

Eighty-one percent of the post-weatherization treatment and post-weatherization comparison group respondents reported that weatherization benefitted their health in other ways as well. The results presented in Table 4.2 suggest that these benefits could be quite significant: $3679 for the post-weatherization treatment group and $2122 for the post-weatherization comparison group. Again, the means are substantially influenced by those households reporting savings of greater than $3000. Unlike the results presented in Table 4.1 though, many fewer households reported no additional health benefits. Spreading these benefits across all homes weatherized in PY 2008 yields a first year savings per unit of $490 and a first year Program benefit of $48M.

[58] Sample sizes (n) for findings presented from the national occupant survey are not reported (with the exception of Asthma section) as the (n) differs insignificantly: 99.9% of occupant survey respondents answered all survey questions.
[59] These calculations assume that all of the surveyed households that did not answer this question would have reported no out-of-pocket savings.

Table 4.1. Estimated Annual Savings in Out-of-Pocket Medical Expenses Since Weatherization

How much do you think you save per year in out of pocket costs for doctor's visits and/or medications since having your home weatherized?(Asked if health improved and at least some attributed to weatherization)

	Post-Weatherization Treatment	Post-Weatherization Comparison 2	Total
Number of Respondents	65	72	137
Nothing	28%	26%	27%
$1 to less than $500	38%	47%	43%
$500 to less than $1,000	18%	13%	15%
$1,000 to less than $1,500	5%	7%	6%
$1,500 to less than $2,000	0%	0%	0%
$2,000 to less than $2,500	8%	3%	5%
$2,500 to less than $3,000	2%	0%	1%
More than $3,000	2%	4%	3%
Median	$250	$200	$200
Mean	$572	$462	$514
TOTAL	100%	100%	100%

Table 4.2. Estimated Value of Additional Health Benefits from Weatherization

How much are these additional benefits worth to you? (Asked if respondent said there were additional benefits from weatherization)

	Post-Weatherization Treatment	Post-Weatherization Comparison 2	Total
Number of Respondents	53	64	117
Nothing	4%	13%	9%
$1 to less than $500	34%	33%	33%
$500 to less than $1,000	11%	11%	11%
$1,000 to less than $1,500	11%	11%	11%
$1,500 to less than $2,000	2%	2%	2%
$2,000 to less than $2,500	6%	8%	7%
$2,500 to less than $3,000	4%	2%	3%
More than $3,000	28%	22%	25%
Median	$1,000	$500	$500
Mean	$3,679	$2,122	$2,827
TOTAL	100%	100%	100%

The last table in this section, Table 4.3, presents results from an inquiry about additional pay received due to fewer absences from work post-weatherization. The mean increase in income for the post-weatherization treatment group is $300, whereas the post-weatherization comparison group reported a much higher income gain, $854. Spreading the former over all weatherization units, the first year per unit benefit is $39 and the first year Program benefit is $3.9M. These estimates are comparable to the detailed analytically-derived estimate contained in Section 4.2.6 below.

Table 4.3. Estimated Annual Additional Pay from Less Work Absences Since Weatherization

How much do you think you've gotten per year in additional pay because you have reduced your absences from work since having your home weatherized? (Asked if health improved and at least some attributed to weatherization)			
	Post-Weatherization Treatment	**Post-Weatherization Comparison 2**	**Total**
Number of Respondents	51	53	104
Nothing	67%	57%	62%
$1 to less than $500	18%	23%	20%
$500 to less than $1,000	6%	6%	6%
$1,000 to less than $1,500	2%	8%	5%
$1,500 to less than $2,000	2%	0%	1%
$2,000 to less than $2,500	2%	2%	2%
$2,500 to less than $3,000	0%	0%	0%
More than $3,000	4%	6%	5%
Median	$0	$0	$0
Mean	$300	$854	$583
TOTAL	100%	100%	100%

Several insights can be gained from these results. First, about one-eighth of respondents were willing to estimate changes in household expenses and income post-weatherization. Second, because of this relatively low response rate, the results in this subsection are not used in the overall monetization of health-benefits attributable to weatherization reported below.

However, the interviewers reported that the respondents who did respond to these questions did so in a focused manner. In other words, they had been closely tracking household expenses and income and did not have difficulty in answering the questions. Therefore, one could argue that a future research study could successfully focus on tracking these types of data more formally, maybe through the use of budget diaries.

4.2 MONETARY BENEFITS OF WEATHERIZATION: ANALYTICAL RESULTS

The discussions presented in Sections 2.0, 3.0 and 4.1 all indicate that weatherization has the potential to deliver a wide range of health benefits to households directly and as well as to society at large. In this section, eleven health and household-related benefits are monetized. The results of these monetization exercises are intended to be added to the monetization of other non-energy benefits of weatherization (e.g.,, environmental) and to the energy cost savings attributable to weatherization to compare to the overall costs of the weatherization program to calculate an overall programmatic benefit-cost ratio.[60] The results found below are also valuable in their own right because they represent one of the first attempts to monetize a comprehensive set of health-related non-energy benefits attributable to any type of weatherization program.

[60] See Carroll et al. (2014c).

Here are the eleven health and home-related non-energy benefits addressed below:

- Reduced Carbon Monoxide Poisonings
- Reduced Home Fires
- Reduced Thermal Stress on Occupants
- Reduced Asthma-Related Medical Care 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

An important reason that these eleven NEBs were chosen for monetization is that the evaluation collected data pertinent to measuring the direct outcomes and/or monetizable outcomes related to each NEB. 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 is used to estimate reduced carbon monoxide poisonings and home fires.

It should be noted that this list excludes some other potential NEBs about which the evaluation also collected data. For example, WAP regularly replaces refrigerators. Several hundred refrigerators were monitored pre-weatherization as part of the Indoor Environmental Quality Study.[61] Analyses indicated a significant number of refrigerators were not operating at acceptable temperature levels, thereby potentially placing household members at risk of food poisoning. Because the analysis of the refrigerator data was scheduled for later in the project, the potential NEB was not included for monetization. However, future research could explore how refrigerator replacements could prevent emergency department visits and hospitalizations, for instance. The evaluation also collected information on various non-energy conservation measures installed in homes, such as stair and floor repairs. Thus, future research could also consider as non-energy benefits incidental repairs that could prevent trips and falls, and reducing the temperature of the water flowing from water heaters could prevent scalding.

Another important reason that these eleven were chosen is that a priori it was assumed that objective cost data could be acquired for input into each monetization approach. By object cost data is meant data from existing databases that contain average costs for specific types of emergency room visits and hospitalizations, for example. This is opposed to including and relying on subjective estimates of monetary value, as would be done through contingent valuation approaches used to estimate non-market-based values. It is not being argued here that NEBs that can only be estimated using subjective means are unimportant. However, the methods used to estimate subjective benefits can be seen as being controversial, and were not pursued by this research. Thus, important subjective NEBs related to weatherization that are not included in this assessment include:

- Enjoyment of the improved comfort of the home
- Feeling better from better night's sleep
- Feeling better from being able to take physician recommended prescriptions
- Reduced worries related to paying bills
- Reduced worries related to being able to afford enough nutritious food for children in the home
- Feeling better from fewer days of asthma-related symptoms

[61] See Pigg et al. (2013) for more information about this study and Goeltz (2014) for results related to refrigerators.

- Feeling better about the improved condition of the home
- Feeling less bothered from outdoor noise infiltrating the home
- Reduced psychological stress of having mold, cockroaches and other pests in the home
- Reduced stress from worries about forced mobility and possible break-up of the family unit

It also needs to be noted that the estimated benefits of the eleven NEBs are only attributed to weatherized single family, small multi-family, and mobile home units (N= 80,352). Weatherization of large multi-family buildings is sufficiently different and occupants of these buildings were not surveyed, so these units have been dropped from the 2008 program totals for these analyses.

For the health benefits addressed below, the period of time that benefits accrue is assumed to be ten years or in one case, five years. This period is shorter than the average energy conservation measure lifetime of 20 years. It was chosen because the health benefits interact strongly with the demographics of households. For example, households that have children with asthma that benefit from reduced asthma symptoms post-weatherization are likely not to have children living in the home much beyond ten years post-weatherization. In ten years, the incidence of asthma in adults could change substantially. Potential changes in climate could also change the baseline incidence of thermal stress. Potential changes in the nation’s economy in general and interest rates in particular could change the baseline rates for food assistance and the use of short-term high interest loans.

Another point that needs to be emphasized is that the benefits attributable to the eleven NEBs listed above can be almost immediately accruable. For example, improved thermal comfort of homes can immediately work to reduce thermal stress. Within the survey time period, households could have saved enough on energy to allow them to buy more food, better afford prescriptions, and make less use of high interest, short-term loans. Left out of the analyses are many health benefits mentioned in Section 2.1 that may take many years to accrue, such as those related to reducing cardiac heart disease and lung cancers, and are beyond the ten year period being used in this study.

Each monetization exercise has the same basic formula. The potential benefit is introduced. The incidence of weatherized homes receiving the benefit is estimated from data collected by the evaluations. The value of the benefit per home receiving and/or generating the benefit is estimated using secondary data sources and/or the literature. Then, the total benefit attributable to WAP is estimated for the first year and over a period of years (typically ten years but less if the expected lifetime of a measure is less). These values are divided by the number of single family, mobile home, and small multifamily units weatherized in PY 2008 to estimate per units benefits in the first year and over ten years.

A key aspect of any comprehensive benefit-cost analysis is the characterization of benefits and costs over time, and the proper discounting of these benefits. As noted above, unless otherwise specified below, the time period covered is ten years. The ten-year discount rate used in this analysis is 0.1%. This is the 10-year real interest rate published for 2013 by the U.S. Office of Management and Budget (OMB).[62] It should be noted that this rate is historically low, as compared to other recent rates and to a long-term average of 3%.

The research presented below apportions each benefit into the three traditional non-energy benefit buckets: households, ratepayer, and society. Benefits attributed to households are directly related to household income and the value of predicted lives saved. Benefits to a health insurance program (private or public), to an employer or to any federal government program are counted as societal benefits. Because no ratepayer benefits were identified in the analyses below, so to simplify the presentation of the results, that category has been dropped from the results tables.

[62] This discount rate is consistent with the 2013 OMB rates used to estimate the NPV of energy cost savings presented in the individual energy impact reports and in the summary impact report.

The results have also been broken out in two other ways. First, the value of saving lives is separated from the other monetized benefits. This was done because the value of a saved life, assumed to be $7.5 million herein, is substantially more than any other specific benefit identified in this research.[63] It should also be noted that this value is not adjusted based on life-expectancy. The U.S. Environmental Protection Agency reports that the 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. Although EPA does not explicitly state that the costs and benefits are intended to reflect societal effects, in this study we apply avoided costs associated with avoided deaths to be a societal benefit.

Second, the results are grouped into three tiers based on their assessed accuracy. Tier One contains the NEBs with the relatively highest accuracy, which at the very least are based on observed survey results and do not have any major methodological issues. Tier Two contains NEBs that may be based on observed survey data but have one or two methodological issues and/or be based on strong programmatic observations (e.g.,, installation of carbon monoxide monitors) but not on direct observations of change. Tier Three contains the NEBs that some may deem as the most speculative. Users of the results presented below can then decide whether or not to use NEBs that may be less accurate than others in their own policy explorations. An extensive and innovate framework was developed to assess uncertainties associated with each monetized estimate. The framework and its application to each of the eleven NEBs listed above are contained in Appendix B. The discussions of each NEB contain a summary of the accuracy assessments at the end of each subsection.

4.2.1 Reduced Carbon Monoxide Poisonings

Carbon monoxide (CO) is a colorless, odorless 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. As this subsection focuses on unintentional and non–fire-related (UNFR) CO poisoning of WAP eligible residents, the disproportionately higher percentages of elderly and people in poor health within this population make them particularly vulnerable to UNFR CO poisoning. Additionally, while proper safety, maintenance, and monitoring can prevent virtually all UNFR CO poisonings, the low-income status of this group can make such precautions unaffordable. As such, these characteristics could put persons eligible for WAP at significantly higher than average risk of UNFR CO poisoning.

Combustion safety is a high priority for WAP. Combustion appliances – furnaces, water heaters, ovens and ranges – are tested for leaks and CO emissions during audits and again during final inspections. All detected combustion safety issues are immediately addressed.

Fortunately for the WAP population, CO problems are relatively rare. As part of the national occupant survey, the treatment and comparison groups were asked this question: In the past 12 months, has anyone in the household been poisoned by breathing in carbon monoxide, and therefore went to see a medical professional? This question was answered yes by only five households out of the 2291 times the question was answered. Results from another evaluation study, this one a study of over five hundred homes that were monitoring for indoor environmental quality (IEQ) pre- and post-weatherization, found few CO problems in homes (Pigg et al. 2013). For example, pre-wx only 2 of 114 homes that relied on the natural ventilation of their heating systems had inadequate draft. Issues with natural-draft water heaters and ovens were somewhat higher, in the 15 percent range in each case. No homes were found to have elevated levels of ambient CO. All detected issues were dealt with by weatherization crews.

[63] For example, EPA has valued a human life for benefit-cost calculations to be more than $7 million (See http://yosemite.epa.gov/ee/epa/eed.nsf/pages/MortalityRiskValuation.html#whatvalue)

Because of the small sample sizes of both the national occupant survey and the IEQ study 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 described below makes heavy use of secondary data, along with direct observation of CO monitors installed by WAP in 2008, to estimate the health-related monetary benefits of installing CO monitors. Specifically, the monetization of the CO benefit presented below has these six components:

1. The number of households and residents potentially benefitting from the installation of CO monitors by WAP for PY 2008 is estimated;

2. The number of ED, hospitalizations and deaths from CO poisoning nationally is estimated;

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

4. Studies that estimate the impacts of installing CO monitors are summarized;

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

6. The monetary values of preventing the ED visits, hospitalizations, and deaths by household and society are estimated.

Characterizing the WAP Population

The first step was to estimate the total number of persons living in homes that received weatherization from a WAP agency in PY 2008. In PY 08, the funds allotted from DOE led to the weatherization of approximately 80,352 units. The reported weatherized units for PY 08 were taken from the report *National Weatherization Assistance Program Characterization: Describing the Pre-ARRA Program* (Bensch, et al. 2013). In estimating the population count of number of people living in weatherized homes in PY 08, data from the *National Weatherization Assistance Program Impact Evaluation: Baseline Occupant Survey* (S4) were used to find the mean persons per family (Carroll, et al. 2014a). The analyzed sample was the "Treatment" group, which consisted of 1,078 individuals who qualified for WAP in PY 11. The number of units (80,352) and average persons per family (2.47) were multiplied and summed to produce a total WAP population of about 242,358 persons living in homes weatherized in PY 08.

Estimating National Health Damages from UNFR CO Poisoning

In "Hospital burden of unintentional carbon monoxide poisoning in the United States, 2007" Iqbal et al. modified the Council of State and Territorial Epidemiologists' definition of CO poisoning based on the *International Classification of Disease, Ninth Revision, Clinical Modification* (*ICD-9-CM*) code to capture the confirmed, probable, and suspected cases of UNFR CO poisoning (Iqbal et al. 2102). To capture the effects of CO poisoning in WAP homes, *ICD-9-CM* codes were further differentiated to exclude codes that describe vehicles in motion, which are irrelevant to CO in the home.[64] US Agency for Healthcare Research and Quality's (AHRQ) Healthcare Cost and Utilization Project (HCUP) provides an online data acquisition service that is compatible with *ICD-9-CM* codes and was used to produce national medical figures.[65] In this study, the medical costs of UNFR CO poisoning were represented by the aggregate of ED visits, hospitalizations, and deaths in the year 2008.

[64] *ICD-9-CM* code descriptions accessed from http://www.cms.gov/medicare-coverage-database/staticpages/icd-9-code-lookup.aspx and http://www.icd9data.com/
[65] http://www.hcup-us.ahrq.gov/

The number of ED visits was determined by inputting the relevant *ICD-9-CM* codes to acquire ED visit counts from the 2008 HCUP Nationwide Emergency Department Sample (NEDS).[66] Because costs associated with ED patients who are admitted to a hospital are included in hospitalization bills, the ED visits represented here are exclusively treat-and-release cases. These cases are categorized by median income of a patient's ZIP code. HCUP defines low income as the lowest quartile of income in a given year. Hospitalization counts were determined similarly from HCUP's Nationwide Inpatient Sample (NIS).[67] As median ZIP code income is a proxy income identifier, the counts from HCUP do not accurately gauge patients' income status. They do, however, provide a relative frequency between these income groups. This was used in conjunction with 2006-2010 American Community Survey (ACS)[68] and 2009 American Housing Survey (AHS)[69] data to adjust counts to representative estimates and to fit them according to WAP's 200% poverty criterion (Table 4.4).

Table 4.4. HCUP Counts of UNFR CO Poisoning Victims Adjusted for Income Relative to 200% Poverty

ED Visit Profile		
Income Level	Count	Percentage
Low	16,128	34.95%
Not Low	30,018	65.05%
All Visits	46,146	100.00%

Hospitalization Profile		
Income Level	Count	Percentage
Low	2,389	41.60%
Not Low	3,354	58.40%
All Visits	5,743	100.00%

Information on deaths caused by residential UNFR CO poisoning were obtained using the Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research (CDC WONDER) system to access "Multiple Cause of Death (MCD) Files, 1999-2010," a dataset from National Center for Health Statistics' (NCHS) Vital Statistics Cooperative Program (VSCP).70 A methodology similar to that of US Consumer Product Safety Commission (CPSC) in constructing their "Non-Fire Carbon Monoxide Deaths Associated with the Use of Consumer Products 2009 Annual Estimates" with MCD data was employed to estimate deaths from home poisoning (Table 4.5) (Hnatov 2012).

Table 4.5. CDC Counts of Residential UNFR CO Poisoning Victims by Location of Death

Location of Death	**Count**
Home	266
Medical Facility from Home Poisoning (derived)	46
Total Home	312

Evaluating Risk of CO Poisoning among National and WAP Populations

Since fuel combustion is the source of CO production in homes, presence of combustion indicates a risk of CO exposure. The number of homes in the US reporting use of combustion was determined by

66 "Introduction to the HCUP Nationwide Emergency Department Sample (NEDS) 2008." http://www.hcup-us.ahrq.gov/db/nation/neds/NEDS2008Introductionv3.pdf
67 "Introduction to the HCUP Nationwide Inpatient Sample (NIS) 2008." http://www.hcup-us.ahrq.gov/db/nation/nis/NIS_Introduction_2008.jsp
68 American Community Survey
69 American Housing Survey 2009 http://www.huduser.org/portal/datasets/ahs/ahsdata09.html
70 Multiple Cause of Death 1999-2010. http://wonder.cdc.gov/wonder/help/mcd.html

selecting 2009 AHS variables that reported types of fuel used for space heating, water heating, and cooking as well as those that implied combustion such as utility bill and heating equipment information. This data was selected among the cases below 200% of the poverty line (Table 4.6). The resulting ratios of home combustion were used with the 2008 US population to generate national figures (Table 4.7).

Table 4.6. US Population Household Income Relative to 200% Poverty

Household Income	Frequency	Percent	US Population
<=200% Poverty	93,681,352	33.07%	100,566,539
>200% Poverty	189,593,128	66.93%	203,527,427
Total	283,274,481	100.00%	304,093,966

Table 4.7. Presence of Residential Combustion in US Homes at or below 200% Poverty

Combustion?	Frequency	Percent	US Population
Yes	68,186,778	72.79%	73,198,220
No	25,494,574	27.21%	27,368,318
Total	93,681,352	100.00%	100,566,539

This process was mirrored using WAP S4 data of the unweatherized "Treatment" group to determine the presence of combustion (Table 4.8) as well as CO monitors (Table 4.9) in WAP qualified homes.

Table 4.8. Presence of Residential Combustion in WAP Qualified Homes

Combustion?	Frequency	Percent	WAP Population
Yes	931	87.34%	174,551
No	135	12.66%	25,311
Total	1,066	100.00%	199,861

Table 4.9. Presence of CO Monitor in WAP Qualified Homes with Residential Combustion

CO Monitor?	Frequency	Percent	WAP Population
Yes	406	44.86%	78,307
No	499	55.14%	96,244
Total	905	100.00%	174,551

Since the HCUP and CDC WONDER data were selected only to include CO poisonings that occurred in the home, the residents of homes with combustion serve as the population of interest. Ratios of UNFR CO poisoning risks for the WAP demographic were estimated by dividing the low-income ED visits and hospitalizations (Table 4.4) by the population below 200% poverty with combustion (Table 4.7). To obtain estimations of CO poisoning victims for the population served by WAP had they not received weatherization (Table 4.10), these ratios were multiplied by the WAP population with combustion (Table 4.8).

Table 4.10. Estimated Risk and Frequency of UNFR CO Poisoning by Severity among the 2008 WAP Population before Weatherization

Severity	Risk of Exposure	Count in WAP Population
ED Visit	0.022%	38.46
Hospitalization	0.003%	5.70
Death	0.00018%	0.32

ED visit and hospitalization counts were significantly affected by the income profile adjustments, thus yielding higher counts for WAP estimates. This could support that WAP eligible persons have a higher likelihood to experience CO poisoning. A method similar to that used for ED visits and hospitalizations was employed to estimate deaths but was altered because income information for decedents was not available in WONDER. The mortality risk ratio instead uses the national population with combustion, regardless of income level, as the denominator. Consequently, the produced non-adjusted death estimate is presumably lower than the actual count.

The Role of CO Monitors in Preventing UNFR CO Poisoning

Although literature on the efficacy of CO monitors to prevent UNFR CO poisoning shows success, the amount of literature specifying the degree to which CO monitors are effective is limited (Runyan et al. 2005). Most such studies focus on specific areas or events and therefore are unsuited for describing the large, representative sample represented by this study (Cook et al.; Harduar-Mordano and Watkins 2011). Proportions were taken from two studies to describe the success rates of CO detectors (Yoon et al. 1998; Krenzelok et al. 1996) (Tables 4.11 and 4.12).

Table 4.11. Preventative Performance of CO Monitors from Krenzelok, et al.1996

ED Visits		
CO Monitor?	**Persons Symptomatic**	**Percentage**
Yes	7	21.21%
No	26	78.79%
Total	33	100.00%
Hospitalizations		
CO Monitor?	**Persons Hospitalized**	**Percentage**
Yes	2	7.69%
No	24	92.31%
Total	26	100.00%

Table 4.12. Preventative Performance of CO Monitors from Yoon, et al. 1998

Deaths		
Total Residential	Preventable with Monitor	Preventable with Monitor
80	52	65.00%

Estimating the Efficacy of WAP UNFR CO Poisoning Prevention

Applying the success of CO monitors to the CO damage estimates can show a portion of how many of the estimated ED visits, hospitalizations, and deaths could have been prevented had this group already been provided WAP services. The assumption is made that for every WAP eligible home with combustion and without a CO monitor, the contractor would deem it necessary and install a monitor. Yet Krenzelok et al. and Yoon et al. show that even with a monitor, some CO poisoning may still occur. Multiplying the estimates of WAP ED visits and hospitalizations (Table 4.10) by the ratios of CO exposed persons without monitors from Krenzelok et al. (Table 4.11), captured this aspect, revealing the supposed CO monitor possession status of symptomatic and hospitalized persons (Table 4.13). These ratios were again applied to the resulting counts to determine the proportion of these persons whose injury would have foreseeably been prevented with a CO monitor (Table 4.14). Similarly, the ratio in Yoon, et al. (Table 4.12) was applied to the death estimate to determine the preventable deaths of this sample. Because this ratio directly defines prevention related to monitor use instead of exposure, it was only applied once (Table 4.14).

Table 4.13. Possession of CO Monitors for Potential Poisonings among the 2008 WAP Population before Weatherization

CO Monitor?	ED Visits	Hospitalizations	Deaths
Total	38.46	5.70	0.32
Yes	8.16	0.44	-
No	30.30	5.26	-

Table 4.14. Estimates of UNFR CO Poisoning Cases Prevented after WAP Installed CO Monitors in 2008

Preventable?	ED Visits	Hospitalizations	Deaths
Total	30.30	5.26	0.32
No	6.43	0.40	0.11
Yes	23.87	4.85	0.21

The preventive capacity of CO monitors is significant. WAP's installation of CO monitors is estimated to have prevented about 24 ED visits, 5 hospitalizations, and 0.21 deaths. Aside from installing CO monitors where necessary, WAP also prevents UNFR CO poisoning through repairs to and replacements of various heating appliances and other home fixtures, which left unchecked could contribute to CO poisoning. With proper maintenance of CO emitting devices along with functioning CO detectors, poisoning is almost entirely preventable (Graber et al. 2007). With this in mind, the previous estimates likely do not reflect the total preventative capacity of WAP services, as they isolate only the medical costs prevented by the installation of CO detectors. It is therefore necessary to capture the damages avoided from the work that prevents dangerous CO emissions.

Valuating the Prevention of WAP UNFR CO Poisoning

With the assumption that all UNFR CO poisonings can be prevented through the repairs, maintenance, and installations performed by WAP, the estimated poisoning cases among the 2008 WAP population before weatherization (Table 4.10) equal the prevented poisonings. Having quantified the impacts of WAP services in a given year through prevented ED visits (38), hospitalizations (6), and deaths (0.32), it is now possible to relate these benefits with monetary figures. In order to increase accuracy involving medical cost rates, ED visit and hospitalization cases were stratified by primary payer using HCUP and S4 data. Since ED visit cases in NEDS do not contain cost information, the mean costs for ED services according to primary payer were obtained from 2008 Medical Expenditure Panel Survey (MEPS) summary data tables (AHRQ). NIS does include mean cost information by primary payer, and ICD-9-CM code 986 "Toxic effect of carbon monoxide," was used as a best estimate for hospitalizations. The estimated prevented deaths from residential UNFR CO poisoning in 2008 were subjected to US Environmental Protection Agency's Value of a Statistical Life (EPA VSL) of $7.5 million per life (EPA).

Table 4.15 provides a summary of estimated poisoning cases, average costs, and total costs prevented by WAP.

Table 4.15. Prevented Counts and Costs of UNFR CO Poisonings for the PY08 WAP Population in the First Year

<table>
<tr><th>Coverage Type</th><th>Variable</th><th>ED Visits</th><th>Hospitalizations</th><th>Deaths</th></tr>
<tr><td rowspan="3">Private/Other</td><td>Preventable with WAP</td><td>9.76</td><td>0.97</td><td></td></tr>
<tr><td>Mean Cost per Count</td><td>$1,337</td><td>$5929</td><td></td></tr>
<tr><td>Total Prevented Cost</td><td>$13,046</td><td>$5744</td><td></td></tr>
<tr><td rowspan="3">Medicaid</td><td>Preventable with WAP</td><td>15.28</td><td>1.67</td><td></td></tr>
<tr><td>Mean Cost per Count</td><td>$842</td><td>$10,796</td><td></td></tr>
<tr><td>Total Prevented Cost</td><td>$12,864</td><td>$10,975</td><td></td></tr>
<tr><td rowspan="3">Medicare</td><td>Preventable with WAP</td><td>7.54</td><td>2.59</td><td></td></tr>
<tr><td>Mean Cost per Count</td><td>$2,285</td><td>$11,807</td><td></td></tr>
<tr><td>Total Prevented Cost</td><td>$17,232</td><td>$30,633</td><td></td></tr>
<tr><td rowspan="3">Uninsured</td><td>Preventable with WAP</td><td>5.88</td><td>0.47</td><td></td></tr>
<tr><td>Mean Cost per Count</td><td>$1,203</td><td>$7,223</td><td></td></tr>
<tr><td>Total Prevented Cost</td><td>$7,075</td><td>$3,390</td><td></td></tr>
<tr><td rowspan="4">Total</td><td>Preventable with WAP</td><td>38.46</td><td>5.70</td><td>0.32</td></tr>
<tr><td>Mean Cost per Count</td><td>$1,305</td><td>$10,134</td><td>$7,501,846</td></tr>
<tr><td rowspan="2">Total Prevented Cost</td><td>$50,218</td><td>$57,743</td><td>$2,417,314</td></tr>
<tr><td colspan="3">$2,525,000</td></tr>
</table>

These benefits are then divided into household benefits and societal benefits (Table 4.16). This was done by applying primary payer information from HCUP and MEPS Household Component Event Files[71]. Cases paid by Medicare and Medicaid are considered societal benefits, while uninsured cases are household benefits. Cases whose primary payer was private/other are split between societal and household according to individual/out of pocket payment proportions from MEPS.

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

Table 4.16. Household and Societal Benefits from Avoided UNFR CO Poisonings for the PY08 WAP Population in the First Year

Coverage Type	Variable	ED Visits	Hospitalizations	Deaths
Private/Other	Total Prevented Cost	$13,046	$5,745	
	Household Ratio	15%	6%	
	Societal Ratio	85%	94%	
	Household Cost	$1,982	$367	
	Societal Cost	$11,064	$5,378	
Medicaid	Total Prevented Cost	$12,865	$17,976	
	Household Ratio	0%	0%	
	Societal Ratio	100%	100%	
	Household Cost	$0	$0	
	Societal Cost	$12,865	$17,976	
Medicare	Total Prevented Cost	$17,232	$30,633	
	Household Ratio	0%	0%	
	Societal Ratio	100%	100%	
	Household Cost	$0	$0	
	Societal Cost	$17,232	$30,633	
Uninsured	Total Prevented Cost	$7,076	$3,390	
	Household Ratio	100%	100%	
	Societal Ratio	0%	0%	
	Household Cost	$7,076	$3,390	
	Societal Cost	$0	$0	
Total	Household Cost	$9,058	$3,757	$0
	Societal Cost	$41,161	$53,986	$2,417,314
	Household Cost	$12,815		
	Societal Cost	$2,512,461		

Additionally, the CO poisoning aversion benefits of WAP services certainly transcend the year in which they were received, as the repairs and installations of preventative measures continue to protect residents for years afterward. CO detectors vary in lifespan according to model, but they generally remain effective for an average of five years (Rickerl 2012; North Shore Fire Department 2011; BRK Brands, Inc. 2011). Other measures commonly performed by WAP contractors may provide benefits much longer. Installation of safer and more efficient combustion appliances may reduce CO poisoning risks for years beyond the life of a CO monitor, while such reduction lasts indefinitely in cases in which combustion is replaced or reduced with grid electricity and energy efficiency. Yet as timeframes of such benefits are incredibly diverse and vary significantly from case to case, the stream of benefits across time cannot accurately be measured. However, it is likely that these preventative measures function as intended for at least the five years the CO detector remains operational. Thus the assumption remains that virtually all CO poisoning will be prevented during the five years following weatherization. Avoided costs of CO poisoning were discounted over five years to estimate the present value (PV) of total savings in health damages in this period. The five-year real treasury interest rate for 2013 (-0.8%) from OMB was used in these calculations (Zients 2013). These results are presented in Table 4.17.

Table 4.17. Monetization of Benefits Attributable to Reducing CO Poisoning

Beneficiary	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 5 Years	PV Per Unit Benefit Over 5 Years
Households	$12,815	$0.16	$65,642	$0.78
Society	$2,512,461	$31.27	$12,869,520	$152.67
Total	**$2,525,276**	**$31.43**	**$12,935,162**	**$153.45**

Accuracy Assessment: It is logical to contend that weatherization can reduce CO poisoning through the installation of CO monitors. A robust national sample of local weatherization agencies provided information on weatherization measures installed in over 10,000 weatherized homes in PY 2008. Thus, the estimate of the number of CO monitors installed by WAP in PY 2008 is reliable. Due to the relatively rare occurrence of CO poisoning in homes, secondary data on the relationship between CO monitors and the prevention of CO poisoning was used. Medical costs data were no observed but were drawn from an up-to-date national medical cost database. Deaths prevented from the installation of CO monitors were estimated from secondary sources. Because the benefit under consideration, reduced CO poisoning, was not directly observed but the other data are high in quality, the monetized estimate from reduced CO poisoning from the installation of CO monitors is placed in Tier 2.

4.2.2 Reduced Home Fires

Unintentional Residential Structure Fires

In 2008, the United States saw 378,000 unintentional residential structure fires cause 2,390 deaths, 12,610 injuries, and $7.69 billion in property loss (Miller 2012). While numerous factors influence home fire occurrence and intensity, certain populations are particularly vulnerable. Persons who are elderly, live in old homes, or have low incomes 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 WAP population, WAP 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. As a retrofitter of homes at risk to fire, WAP addresses many such causes and contributors of fires. This section intends to quantify fire risk in WAP-eligible homes and to estimate the influence of WAP on curbing potential for fire damages.

Occupant Survey Limitations

The Occupant Survey (S4) contains three questions that directly address home fires:

*In the past 12 months how many times has the fire department been called to put out a fire in your home?*__________________[72]

*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?*__________________[73]

In the past 12 months, how many individuals needed medical attention because of fire?
__________________[74]

---

[72] Treatment Pre-Wx: 8 calls out of 665 responses. Treatment Post-Wx: 1 call out of 398 responses. Comparison 1: 8 calls out of 802 responses. Comparison 2: 0 calls out of 430 responses.

[73] Treatment Pre-Wx: 7 fires out of 665 responses. Treatment Post-Wx: 4 fires out of 398 responses. Comparison 1: 6 fires out of 803 responses. Comparison 2: 3 fires out of 430 responses.

While these questions address key aspects of fire, several factors restrict their ability to properly gauge fire risk among the WAP population. First, the S4's sample size could be too small to accurately describe fire frequency and consequence. This section estimates 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, a pre- and post-treatment survey method may exclude extreme fire events. Major fire damage in a WAP-eligible household could result in an occupant's death, relocation, or deferral of WAP services, which would prevent survey participation.

Summary of WAP Fire Prevention Estimation Methodology

Fire risk and prevention among WAP households in single-family buildings follows these steps (Figure 4.1):

1. National fire data are subset to include primary fires in one- and two-unit residential buildings.
2. General causes of these fires are determined and cases with unknown or invalid causes are excluded.
3. Common weatherization measures with fire prevention capacities are linked with specific contributors to fire ignition and spread.
4. Fire incidents are identified by the presence of weatherization-preventable contributors to fire.
5. Zip code-level housing and poverty data are matched with each fire to construct sample weights to estimate fire frequency among households under 150 percent of the poverty level.
6. Fires and subsequent damages are weighted to estimate national totals.
7. Probabilities of fire occurring in WAP homes are estimated using fire incidents and total homes among single-family households whose income is less than 150 percent of the poverty level.
8. These probabilities are applied to the 80,352 single-family and mobile homes that received WAP services in 2008.

Estimating Fire Occurrence and Selected Consequences among the WAP Population

Fire frequency and fire damage estimates came from the US Fire Administration's (USFA) National Fire Incident Reporting System (NFIRS). The current NFIRS 5.0 compiles and standardizes fire incident data voluntarily reported from about 23,000 fire departments in the United States. Table 4.18 presents the total fire incidents among several NFIRS scopes between 2008 and 2011. Depending on the nature of the fire and the thoroughness of the fire department, each incident can be described by a few hundred variables, providing valuable information on about 75 percent of fires reported annually. The values of interest came from six variables: fire service deaths, fire service injuries, other deaths, other injuries, property loss, and contents loss. "Fire service" refers to firefighters and "other" refers to civilians. Property loss and contents loss are rough dollar estimates made onsite by fire responders.

Beginning with more than 8.78 million records across four years, incidents were selected as to only include fires that WAP measures could feasibly address. USFA supplies NFIRS coding definitions for residential building fires. These were altered to fit the scope of this study, namely excluding residential

[74] Treatment Pre-Wx: 0 medical emergencies out of 665 responses. Treatment Post-Wx: 0 medical emergencies out of 398 responses. Comparison 1: 4 medical emergencies out of 803 responses. Comparison 2: 0 medical emergencies out of 430 responses.

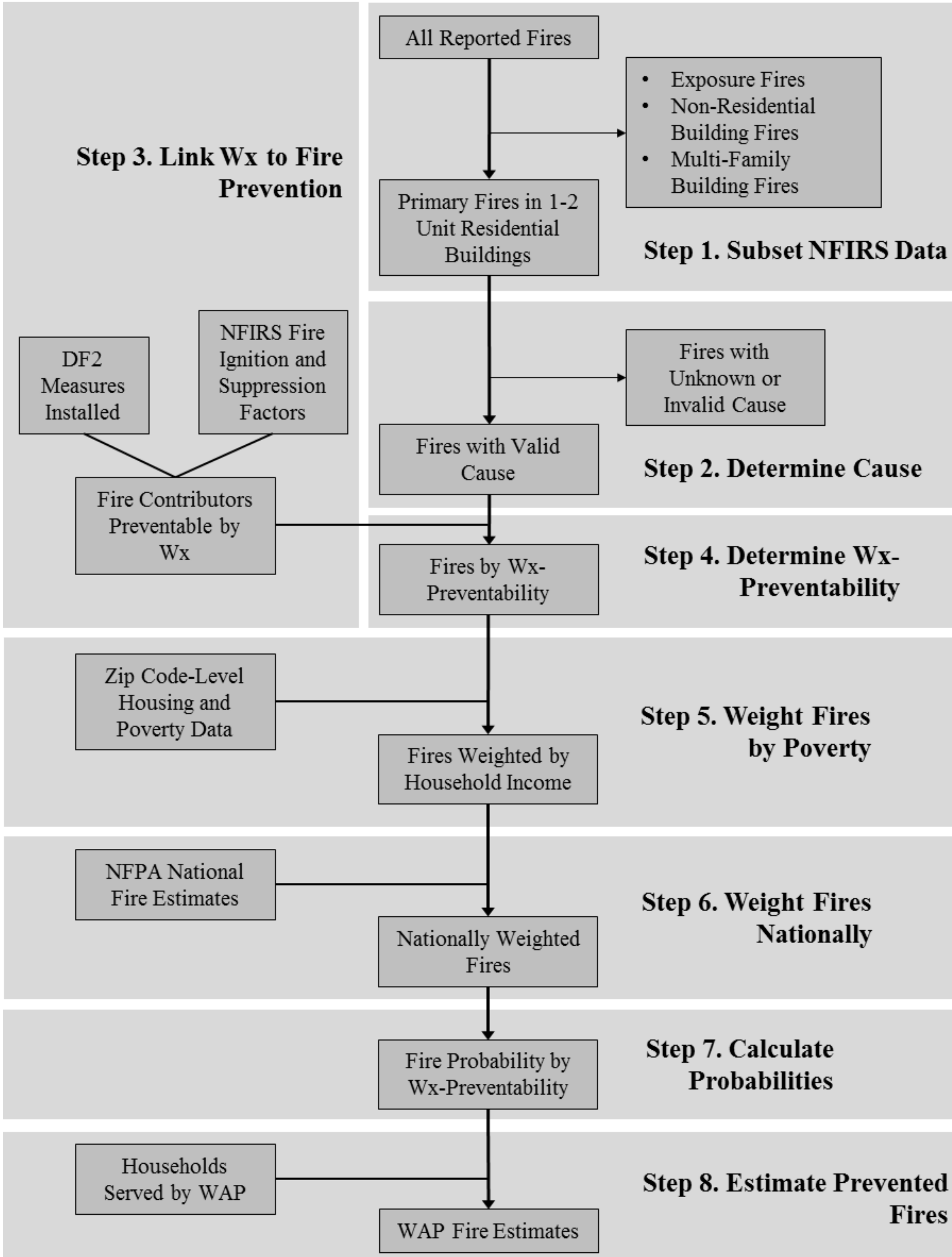


Figure 4.1. Overview of WAP Fire Prevention Estimation Methodology

buildings such as hotels and dormitories, which do not receive WAP services. Additionally, since this report focuses on single-family homes, all in-scope fires initiated in one- and two-family residential buildings, including mobile homes. While relatively uncommon, extreme cases of residential fires may spread to other structures, i.e. exposure fires. Because exposure fires can involve much complexity and uncertainty regarding the attribution of cause, exposure fires were excluded from analysis so that only primary fires remained. Consequently, final estimates do not contain any damages, injuries, and deaths resulting from exposure fires, thus should be considered conservative in this regard.

Table 4.18. Total Incidents among Several NFIRS Scopes, 2008-2011

Year	All Cases	Residential Building	Residential Building Single-Family	Residential Building Single-Family Primary Fire
2008	2,178,599	251,571	166,575	163,049
2009	2,072,850	248,734	163,504	160,833
2010	2,221,660	270,240	176,788	173,600
2011	2,311,716	269,297	175,593	172,342
All	**8,784,825**	**1,039,842**	**682,460**	**669,824**

Determining Fire Cause

As WAP can only play a role in fires involving certain causes, it is necessary to determine causes for incidents in NFIRS. To attribute cause to each fire incident in NFIRS, USFA has developed a hierarchical cause matrix. This method assigns 35 mutually exclusive priority causes, using prioritized combinations of specified data entries. As these causes are not included before the 2011 data release, USFA advises creating a script to run queries based on the cause matrix. This was programmed using R to assign causes for all four years of data and was compared with the 2011 file for quality assurance.[75] USFA generalizes these 35 priority causes into 16 mid-level causes and again into seven general causes. Fires in the unknown categories were then excluded from further analysis. Further discussion on the treatment of cause categories is found in the following text and Table 4.19.

An incredibly diverse set of factors contributes to the ignition and spread of fires in homes, making each incident unique. The vast heterogeneity in circumstances surrounding fire makes fires difficult to predict and subsequently to prevent or at least to limit its effects. This is not to say that fire prevention is not well understood; certain aspects such as smoke detectors, evacuation, and construction considerations have been frequently studied and written into building codes (Liu, et al. 2012; Bruck, et al. 2010; Kobes, et al. 2009; Hadjisophocleous, et al. 1999). Although several fire safety models have been developed using such codes, they were not suitable in demonstrating fire prevention in the context of WAP retrofits with given information (Watts, et al. 2001). Though such models and building codes were consulted, a WAP-specific fire risk framework was developed primarily from NFIRS and WAP Housing Unit Information Survey (DF2) data.

Linking Weatherization Measures to Fire Prevention

A basic framework for the fire risk model was first compiled by observing two frequency variables from the NFIRS fire incident module: equipment involved in ignition (EQUIP_INV) and fire suppression factors (SUP_FAC_x). The EQUIP_INV variable predominantly deals with the fire's origin, which can be listed as one of nearly 300 items causing ignition. SUP_FAC_x is involved with fire growth and spread and consists of three variables with about 130 factors, allowing for optional multiple responses. Regarding the output from these variables as major contributors to fire, corresponding WAP measures that would address fire ignition and spread were searched for in the DF2 file (Figure 4.2). The relevant measures were split into 17 categories, and SUP_FAC_x and EQUIP_INV responses were stratified accordingly to make 17 weatherization measure dummy variables in NFIRS. Nine dummy variables used values from EQUIP_INV (EI1-EI9), and eight dummies were derived from SUP_FAC_x (SF1-SF8). A crosswalk for all 17 categories can be found in Appendix C. Table 4.19 shows weighted (more on this

[75] R is a free programming language and statistical package. The version used in this analysis was R version 3.0.2 (2013-09-25) -- "Frisbee Sailing" Copyright (C) 2013 The R Foundation for Statistical Computing

follows) frequencies of these dummy variables in regards to measures installed and their involvement in WAP fires.

Table 4.19. Weighted Estimates of Fire-related Weatherization Measures Categories and Their Potential in Fire Prevention

Wx Fire Prevention Dummy	EI/SF Dummy Label	Weighted DF2 Homes	Percent of Wx Units	WAP Weighted NFIRS Fires	Percent of Fires
EI1	Electrical	4,324	5.38%	8.85	2.96%
EI2	Heating	39,128	48.70%	10.76	3.60%
EI3	Cooling	4,969	6.18%	1.54	0.51%
EI4	Clothes Dryer	16,086	20.02%	6.18	2.07%
EI5	Refrigerator	11,918	14.83%	0.80	0.27%
EI6	Water Heater	44,340	55.18%	2.53	0.85%
EI7	Chimney	2,176	2.71%	1.88	0.63%
EI8	Fans	11,205	13.94%	1.38	0.46%
EI9	Lighting	51,556	64.16%	1.52	0.51%
No EI	No EI1-EI9	1,399	1.74%	263.40	88.14%
SF1	Smoke Alarm	36,619	45.57%	3.14	1.05%
SF2	Windows,Doors	39,805	49.54%	1.29	0.43%
SF3	Ventilation	19,229	23.93%	1.97	0.66%
SF4	Air Sealing	75,673	94.18%	1.28	0.43%
SF5	Wall	25,291	31.48%	2.28	0.76%
SF6	Roof,Attic,Ceiling	51,624	64.25%	6.53	2.19%
SF7	Floor	20,226	25.17%	1.11	0.37%
SF8	Gas	1,061	1.32%	0.47	0.16%
No SF	No SF1-SF8	1,667	2.07%	283.87	94.99%
Total	-	80,352	-	298.84	-

"Wx": Weatherization, "EI": Equipment Involved Dummy Variable, "SF": Suppression Factor Dummy Variable, "DF2": WAP Housing Unit Information Survey

Identify Fires by Weatherization Preventability

If any of these 17 categories were determined to have been involved in a fire incident, then that fire is considered to have been preventable by weatherization. Because NFIRS does not require response for SUP_FAC_x variables, many cases have blank values. These incidents were excluded so that only cases with valid entries (including entries of "no suppression factors involved") remained in scope. Further adjustments were made to cases in regards to their ability to be prevented by WAP (Case Action column in Table 4.20). Among incidents with the cause matrix categories of fireworks, explosives, cooking, or playing with a heat source, ignition would likely not be prevented by weatherization, but WAP measures may aid in reducing spread and damage. To ensure the ignition of such fires were not considered weatherization-preventable, EQUIP_INV values were erased for these cases. Yet the SUP_FAC_x values, which describe weatherization-preventable factors after ignition, were kept. However, all EQUIP_INV and SUP_FAC_x values for arson and natural fires were nullified, as these cases may have had circumstances in which no fire prevention measures would be effective. For example, an arsonist may disable otherwise functional smoke alarms or a storm may contribute to the collapse of a structurally sound building. Overall, the practice of erasing these values ensures that cases with these causes are still recorded as fires among the WAP population but removes the possibility that these incidents are considered preventable by weatherization. This methodology conservatively selected incidents that could have been prevented by weatherization so as not to overestimate this figure. Weatherization likely could have played a role in deterring or minimizing in many of the nullified cases.

Weighting Fire Incidents by Poverty

Since only those households under 150 percent of the poverty level were eligible for WAP services in 2008, NFIRS data needed to be weighted by this income threshold. Several studies have used median incomes of census tracts in studying relationships between fires and household income (Shai, et al. 2003; Istre, et al. 2001). Although NFIRS does have a variable for census tract, about 80 percent of cases have missing or erroneous data. However, zip code data were reliable for nearly 98 percent of cases.[76] These were used to match NFIRS data with zip code-level counts of one- and two-unit households as well as the portion of those homes under 150 percent poverty. Four summary tables from US Census Bureau's Five-Year American Community Survey (ACS) 2008-2012 included housing information by zip code that was adjusted to attain the desired scope (Appendix C).[77]

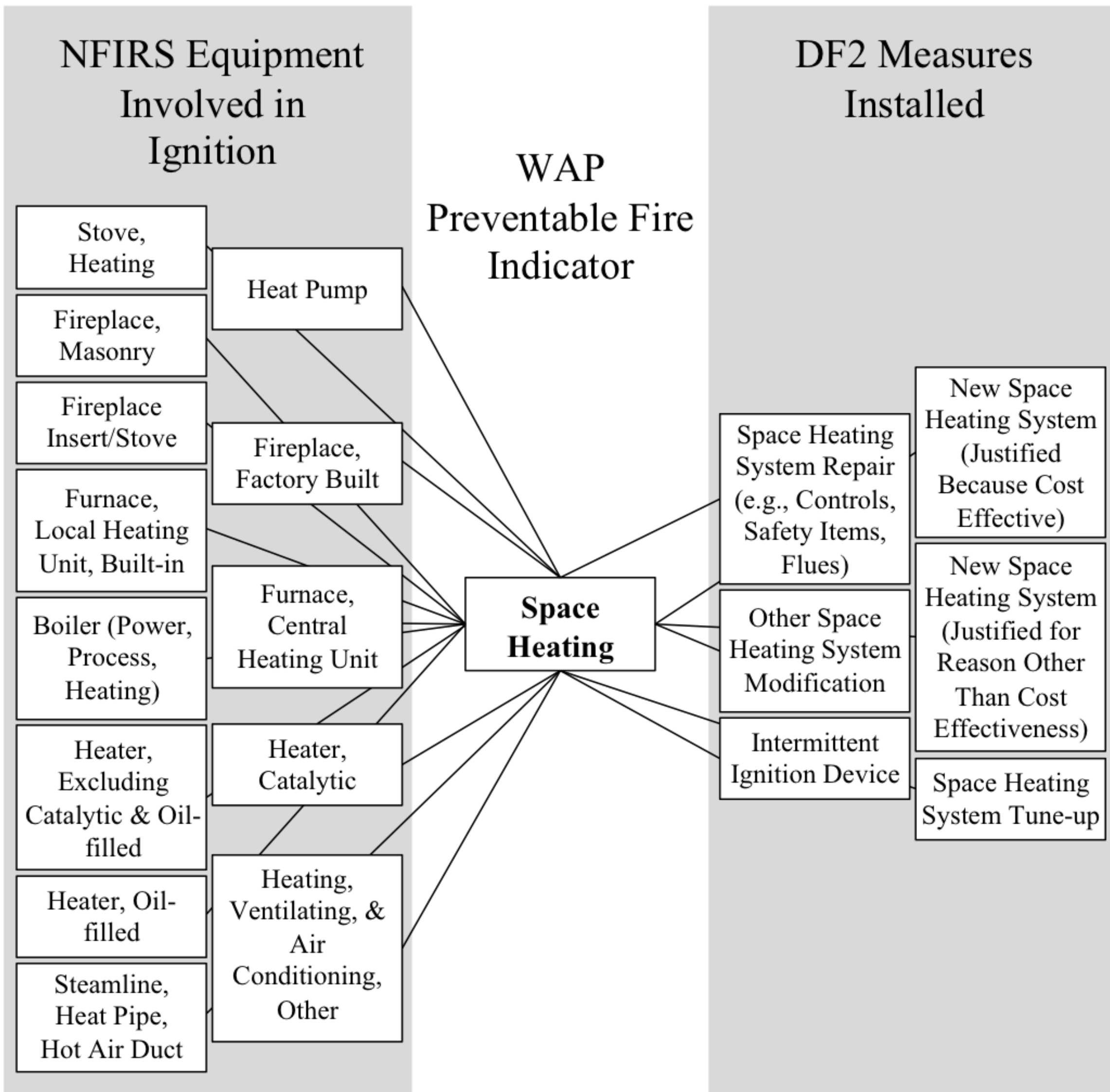


Figure 4.2. Example of NFIRS/DF2 Matchup

[76] About 1500 in-scope cases lacked valid zip codes, yet largely had otherwise valid addresses. These addresses were geocoded to find valid zip codes using the R package ggmap developed by Kahle and Wickam (2013), which accesses Google Maps data. This method was unsuccessful for less than 100 cases, of which about 70 were found via Bing Maps and web queries. The remaining cases were dropped. More information on ggmap: http://cran.r-project.org/web/packages/ggmap/ggmap.pdf

[77] U.S. Census Bureau, 2008-2012 American Community Survey http://www2.census.gov/acs2012_5yr/summaryfile/ACS_2008-2012_SF_Tech_Doc.pdf

Table 4.20. USFA Fire Cause Descriptions, Frequencies, and Treatment of Equipment Involved (EI) and Suppression Factor (SF) Variables

General Cause Description	Cause Description	Priority Cause Description	Count	Percent	Case Action
Exposure	Exposure	Exposure	NA	NA	Already Excluded
Firesetting	Intentional	Intentional	29,177	4.45	Clear EI/SF
Unknown	Investigation with Arson Module	Investigation with Arson Module	6,674	1.02	Exclude
Firesetting	Playing with Heat Source	Children Playing	1,987	0.30	Clear EI
		Other Playing	2,020	0.31	Clear EI
Natural	Natural	Natural	12,849	1.96	Clear EI/SF
Flame, Heat	Other heat	Fireworks	564	0.09	Clear EI
		Explosives	423	0.065	Clear EI
	Smoking	Smoking	10,792	1.65	Clear EI
Equipment	Heating	Heating	91,840	14.01	As is
	Cooking	Cooking	171,262	26.12	Clear EI
	Appliances	Air Conditioning	3,609	0.55	As is
Electrical	Electrical Malfunction	Electrical Dist.	10,904	1.66	As is
Equipment	Appliances	Appliances	11,191	1.71	As is
	Other Equipment	Special Equip.	1,828	0.28	As is
		Processing Equip.	61	0.0093	As is
Flame, Heat	Open Flame	Torches	1,697	0.26	As is
Equipment	Other Equipment	Service Equip.	127	0.019	As is
		Vehicle, Engine	2,324	0.35	As is
		Unclassified fuel powered equip.	373	0.057	As is
Unknown	Unknown	Unclassified equip. w/ other or unknown fuel source	22,140	3.38	Exclude
Electrical	Electrical Malfunction	Unclassified elec malfunction	39,824	6.07	As is
Flame, Heat	Open Flame	Matches, Candles	11,005	1.68	As is
		Open fire	7	0.0011	As is
	Other heat	Other open flame, spark	7,370	1.12	As is
		Friction, hot material	2,285	0.35	As is
	Open Flame	Ember, rekindle	18,256	2.78	As is
	Other heat	Other hot object	11,327	1.73	As is
Unknown	Other Unintentional, Careless	Heat Source or Product Misuse	18,397	2.81	As is
Equipment	Equipment Misoperation, Failure	Equipment Operation Deficiency	13,498	2.06	As is
		Equipment Failure, Malfunction	8,445	1.29	As is
Unknown	Unknown	Trash, rubbish	21,362	3.26	Exclude
Unknown	Other Unintentional, Careless	Other Unintentional	24,776	3.78	Exclude
Exposure	Exposure	Exposure 2	1,009	0.15	Exclude
Unknown	Unknown	Unknown	96,217	14.68	Exclude
Total			**655,620**	**100**	-

The dataset of primary one- and two-unit residential building fires with known cause was aggregated to show the frequency of such fires by zip code. These frequencies were divided by four years to create average annual frequencies, which were then divided by their zip code's number of one- and two-unit households, yielding each zip code's fire rate for this sample. This average fire rate was regressed on a zip code's percent of one- and two-unit houses below 150 percent of the poverty rate. The relationship between this poverty threshold and fire frequency is positive and highly significant ($p < 0.001$) (Table 4.21). This univariate regression model is then used weight the individual fire incidents to estimate the number of fires that occurred in 1-2 unit homes below 150 percent poverty. Each of the 17 weatherization dummy variables was also aggregated by zip code and divided by fire frequency to determine rates that indicate the frequency of each weatherization-preventable category's involvement in these fires. These rates were also individually regressed on zip code-level poverty rate. Nine of these dummy variable models were significant at a 90 percent confidence level. Each significant model was fit on the fire incident dataset, while the dummies without significant relationships to income are not weighted. This effectively weights the dummies relative to one another. It was then necessary to use these weighted dummy variable in order to weight each fire incident. Case weights were created using the proportion of the sum of each case's original dummy variables and the sum of each case's model-weighted dummy variables. The resulting weights make the sample better represent the relationship between poverty and the frequency of weatherization-preventable fires.

Weighting Fire Incidents to National Estimates

While NFIRS describes a large majority of national fires, it does not include all incidents and contains many cases for which this study's variables of interest are unknown. Yet to derive the desired probabilities, incidents must be weighted to national estimates. Each year, the National Fire Protection Association (NFPA) uses data from their National Fire Experience Survey to make national estimates of fire loss, which are endorsed by USFA. The national estimate weights for fire incidents in this study's scope were created using NFPA estimates for each year according to USFA guidelines and methodologies (Karter, Jr. 2009, 2010, 2011, 2012; Fahy, et al. 2009, 2010, 2011, 2012; Karter, Jr., et al. 2009, 2010, 2011, 2012).[78] [79] In calculating national estimates of residential building fires, USFA advises multiplying the ratio of residential building fires to residential structure fires found in NFIRS by the NFPA national structure fires estimate.[80] The resulting residential building fires estimate was multiplied by the proportion of residential building fires that occur in one- and two-unit homes and again by the proportion of those fires that were primary incidents. This was then multiplied by the proportion of weatherization-preventable fires among the known cause subset. Similar processes were followed in estimating deaths, injuries, and dollar loss in residential building fires.

Both NFPA and NFIRS treat firefighter casualties differently than they do fires, property loss, and civilian casualties, so the national estimate methodology is modified accordingly. NFPA reports firefighter casualties by type of duty: responding/returning, fireground, nonfire emergency, training, and other on-duty. Although injuries and deaths labeled responding/returning or other on-duty could be attributed to fire incidents, the nature of such casualties introduces complications for both attribution and monetization. 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. Weights for these firefighter casualties were created by a similar process of subsetting data and multiplying their proportions by the NFPA national estimates. The resulting figures are national estimates of fires, injuries, deaths, and property loss by weatherization

[78] "National Fire Incident Reporting System Complete Reference Guide" http://www.nfirs.fema.gov/documentation/reference/
[79] "National Fire Incident Reporting System Version 5.0 Fire Data Analysis Guidelines and Issues" http://www.usfa.fema.gov/downloads/pdf/nfirs/nfirs_data_analysis_guidelines_issues.pdf
[80] "National Estimates Methodology for Building Fires and Losses" http://www.usfa.fema.gov/downloads/pdf/statistics/national_estimate_methodology.pdf

preventability among primary one- and two-unit residential building fires for each year from 2008 to 2011 (Table 4.22).

Table 4.21. Summary of Poverty Weighting Models

Dependent Variable	EI/SF Label	Constant Value	ß-Coefficient for % Hhds in Zip Code < 150% Poverty	Model R^2	DF	p-value
Mean Annual Fires/1-2 Unit Households	-	0.000242	0.00254	0.01480	13297	0.00000****
EI1 Freq/Fires	Electrical	0.0308	0.0134	0.00016	13297	0.14200
EI2 Freq/Fires	Heating	0.0537	-0.00115	0.00000	13297	0.92100
EI3 Freq/Fires	Cooling	0.00183	0.00713	0.00065	13297	0.00333***
EI4 Freq/Fires	Clothes Dryer	0.0283	-0.0222	0.00075	13297	0.00157***
EI5 Freq/Fires	Refrigerator	0.00487	-0.00350	0.00008	13297	0.28900
EI6 Freq/Fires	Water Heater	0.00731	0.00584	0.00013	13297	0.19200
EI7 Freq/Fires	Chimney	0.0200	-0.0180	0.00052	13297	0.00835***
EI8 Freq/Fires	Fans	0.00876	-0.0102	0.00054	13297	0.00741***
EI9 Freq/Fires	Lighting	0.0115	-0.0142	0.00076	13297	0.00149***
SF1 Freq/Fires	Smoke Alarm	0.0285	-0.0217	0.00053	13297	0.00807***
SF2 Freq/Fires	Windows,Doors	0.00609	0.00796	0.00021	13297	0.09550*
SF3 Freq/Fires	Ventilation	0.0147	0.00753	0.00008	13297	0.29600
SF4 Freq/Fires	Air Sealing	0.00484	0.0195	0.00096	13297	0.00035****
SF5 Freq/Fires	Wall	0.0164	0.00138	0.00000	13297	0.84900
SF6 Freq/Fires	Roof,Attic,Ceiling	0.0336	0.0633	0.00207	13297	0.00000****
SF7 Freq/Fires	Floor	0.00753	0.00511	0.00007	13297	0.33400
SF8 Freq/Fires	Gas	0.6420	-0.00151	0.00002	13297	0.64200

**** p<.001; *** p <.01; ** p<.05; * p<.1

Table 4.22. NFIRS Frequencies and National Estimates of Damage from Primary Fires in One- and Two-Unit Residential Buildings

Year		2008	2009	2010	2011	All
Fires	**NFIRS**	163,049	160,833	173,600	172,342	669,824
	National Estimate	248,804	233,854	236,608	237,546	956,811
Firefighter Deaths	**NFIRS**	5	3	3	1	12
	National Estimate	11	8	5	3	27
Firefighter Injuries	**NFIRS**	1,990	2,153	2,206	2,186	8,535
	National Estimate	16,687	15,467	15,064	14,465	61,683
Other Deaths	**NFIRS**	1,116	1,084	1,162	1,149	4,511
	National Estimate	2,199	1,977	2,040	1,970	8,186
Other Injuries	**NFIRS**	4,547	4,643	5,039	5,093	19,322
	National Estimate	8,422	8,147	8,561	8,965	34,095
Property Loss ($ Millions)	**NFIRS**	2.97	2.91	2.98	2.90	11.8
	National Estimate	5.87	5.75	5.29	5.10	22.0

Estimating Probabilities and Counts of Prevented Fires

The three sets of weights were applied to the primary one- and two-unit home fire incidents with known cause. This provided four-year averages of such fires and selected consequences among homes below 150% of the poverty level by weatherization preventability (Table 4.23). These figures were aggregated by zip code and matched with their nationally weighted counts of one- and two-unit housing below 150% poverty. The totals of fire incidents and homes were used to determine the probability of fire, from all sources and from weatherization-preventable sources, among homes below this poverty threshold (Table 4.23).

With these probabilities, estimates of fires and their preventability among the single-family homes that received WAP services in 2008 may be generated. Out of 80,352 WAP single family and mobile homes in 2008, about 299 fires would have occurred, resulting in about 27 injuries, 2 deaths, and $5,428,016 in property loss. Of those fires and damages, weatherization could have prevented about 47 fires, 6 injuries, 1 death, and $1,378,643 in property loss (Table 4.23).

Table 4.23. Estimates of Fire Damage among 2008 WAP Households

	Weatherization Preventable	Not Weatherization Preventable	Total
Probability	0.000585	0.00313	0.00372
Fire	46.99	251.86	298.84
Firefighter Deaths	0.00224	0.00361	0.00585
Firefighter Injuries	4.64	13.38	18.02
Other Deaths	0.70	1.72	2.42
Other Injuries	1.64	7.49	9.14
Property Loss	$1,378,643	$4,049,373	$5,428,016

Monetization of Fire Prevention Attributable to WAP

These preventable damages were monetized according to beneficiaries, i.e. household and society. Any damages suffered to firefighters were labeled under the societal category. In general, costs or portions of costs prevented by WAP that would have been covered by homeowners or medical insurance fell into the societal bucket, while out-of-pocket expenses were attributed to households.[81]

Fatalities were monetized with a value of a statistical life (VSL) estimate of about $7.5 million per life (Table 4.25).[82] Fatalities fell into the societal category. Lawrence, et al. 2009 completed a multiyear study for the US Consumer Product Safety Commission (CPSC) on annual fire loss in which residential fire injuries and average costs were estimated according to diagnosis (burn, inhalation, burn + inhalation, trauma, and other) and place of treatment (burn center, other hospital, emergency department, and doctor's office/clinic). Tables from this study were used to generate weights by which prevented injuries were proportionately stratified according to diagnosis and treatment. The resulting table of WAP injuries was multiplied by the average cost table from Lawrence, et al. 2009. This was done immediately for firefighter injuries, while avoided civilian injuries were first categorized into household or societal benefits.

[81] Out-of pocket medical expenses for many families, including those with incomes higher than the WAP eligible population, are at times unable to be paid. If these costs are not eventually settled through a collection service, this may result in unpaid medical bills that may eventually become a societal debt. For the purposes of this study, avoided out-of-pocket medical expenses will still be considered a household benefit as these expenses are ultimately the responsibility of the patient; although we recognize that this could be considered speculative. The complexity of determining the percentage of these costs that would become a societal burden is beyond the scope of this study.

[82] US government agencies use VSL values ranging from $5-9 million in regulatory cost-benefit analysis. As part of the WAP National Evaluation, this study uses a VSL of $6 million in 2000 dollars adjusted for inflation to about $7.5 million in 2008 dollars. See OMB Circular A-4 for more discussion on VSL.

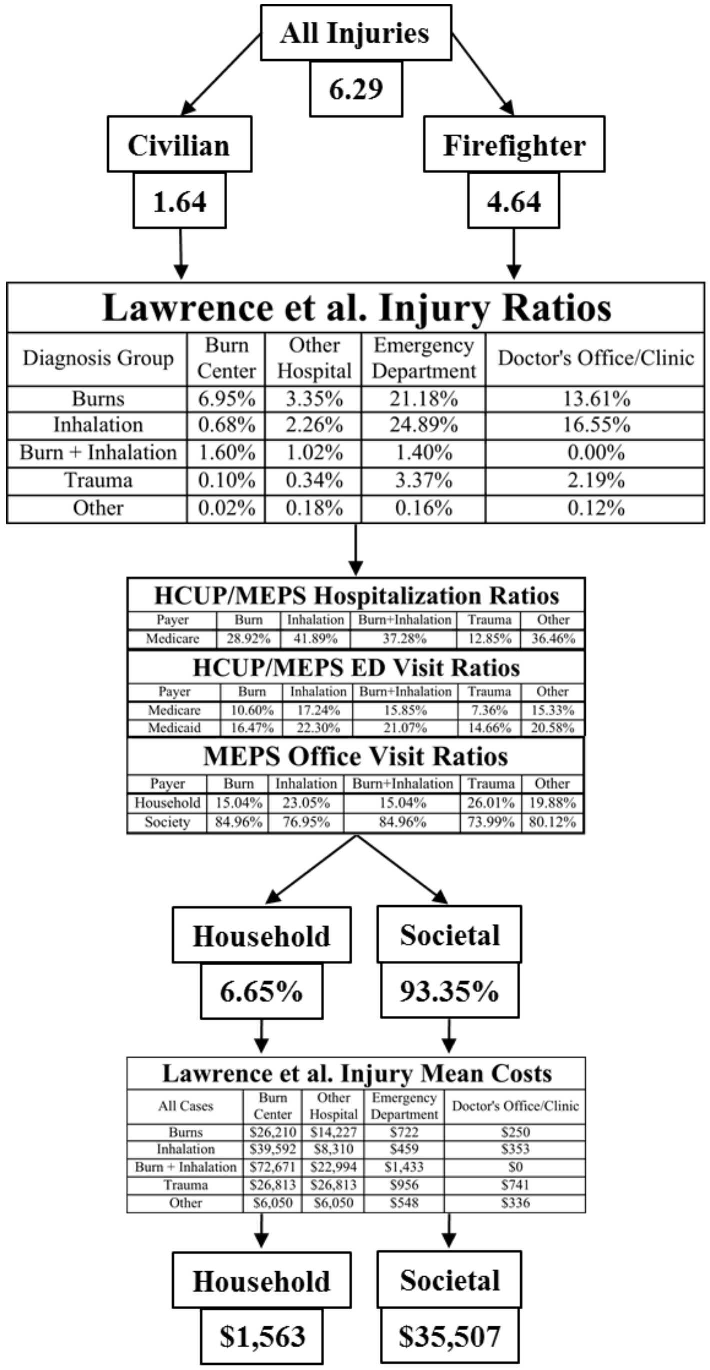
In order to separate civilian injury costs according to household or society, primary payer information was obtained from US Agency for Healthcare Research and Quality's (AHRQ) Healthcare Cost and Utilization Project (HCUP).[83] Relevant *International Classification of Disease, Ninth Revision, Clinical Modification* (*ICD-9-CM*) codes[84] indicating diagnosis were used to generate 2008 frequencies of emergency department (ED) visits from the Nationwide Emergency Department Sample (NEDS)[85] and hospitalizations from the Nationwide Inpatient Sample (NIS).[86] Counts were listed by one of four primary payers, which were portioned into percentages. These percentages were applied to the output from the civilian injury tables. Cases listed under Medicare and Medicaid became societal benefits, uninsured were household, and the private/other category was separated into societal or household based on cost data from the 2008 Medical Expenditure Panel Survey (MEPS).[87] As HCUP does not contain information on doctor's office/clinic visits, MEPS was used exclusively to distribute cases among household and societal benefits in these estimates. With civilian injuries categorized by beneficiary, these estimates were multiplied by the average cost table from Lawrence, et al. 2009 to create total estimates of avoided costs from civilian injuries (Figure 4.3).

Although not necessarily a health benefit, property damage figures are included in NFIRS and used similar methodology as death and injury estimates for WAP. Average costs per fire were calculated, yielding $29,341. Fires were split by beneficiary similar to injuries using homeowners insurance (Figure 4.4). Proportions of homes under 150 percent poverty with or without homeowners insurance were obtained from the 2009 American Housing Survey.[88] The ratios were applied to the primary fires prevented by WAP in 2008 and were multiplied by the average fire loss (Table 4.24). The portion with homeowners insurance counted as a societal benefit, and the portion without was labeled as a household benefit.

Many studies have gone much further into other physical, behavioral, and infrastructural costs involved in fire suppression and prevention, but these aspects are not the focus of this study (Hall 2013, Donahue 2004). Incorporating such costs becomes increasingly problematic in attributing cost-savings to a single entity such as WAP as well as in distinguishing beneficiaries. For example, while including costs for emergency response would likely add a sizable amount to benefits attributable to WAP, there is extensive variability and insufficient data concerning responders, e.g., volunteer vs. paid firefighters, publicly funded vs. fee-charging fire departments.

Because so many aspects are involved in fire safety, it is difficult to predict how the numerous WAP-installed measures will contribute to the reduction of fire risk over time. As a result of this uncertainty, ten years would be the longest time span during which the fire risk reduction could be confidently expected to remain fairly constant. Using the ten-year real treasury interest rate for 2013 (0.1%) from Office of Management and Budget (OMB), a present value (PV) of the total discounted savings from prevented deaths, injuries, and property loss over ten years was calculated (Table 4.26).

[83] Healthcare Cost and Utilization Project (HCUP) http://www.hcup-us.ahrq.gov/
[84] *ICD-9-CM* code descriptions accessed from http://www.cms.gov/medicare-coverage-database/staticpages/icd-9-code-lookup.aspx and http://www.icd9data.com/
[85] "Introduction to the HCUP Nationwide Emergency Department Sample (NEDS) 2008." http://www.hcup-us.ahrq.gov/db/nation/neds/NEDS2008Introductionv3.pdf
[86] "Introduction to the HCUP Nationwide Inpatient Sample (NIS) 2008." http://www.hcup-us.ahrq.gov/db/nation/nis/NIS_Introduction_2008.jsp
[87] MEPS Household Component Event Files http://meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp
[88] American Housing Survey 2009 http://www.huduser.org/portal/datasets/ahs/ahsdata09.html



Lawrence et al. Injury Ratios

Diagnosis Group	Burn Center	Other Hospital	Emergency Department	Doctor's Office/Clinic
Burns	6.95%	3.35%	21.18%	13.61%
Inhalation	0.68%	2.26%	24.89%	16.55%
Burn + Inhalation	1.60%	1.02%	1.40%	0.00%
Trauma	0.10%	0.34%	3.37%	2.19%
Other	0.02%	0.18%	0.16%	0.12%

HCUP/MEPS Hospitalization Ratios

Payer	Burn	Inhalation	Burn+Inhalation	Trauma	Other
Medicare	28.92%	41.89%	37.28%	12.85%	36.46%

HCUP/MEPS ED Visit Ratios

Payer	Burn	Inhalation	Burn+Inhalation	Trauma	Other
Medicare	10.60%	17.24%	15.85%	7.36%	15.33%
Medicaid	16.47%	22.30%	21.07%	14.66%	20.58%

MEPS Office Visit Ratios

Payer	Burn	Inhalation	Burn+Inhalation	Trauma	Other
Household	15.04%	23.05%	15.04%	26.01%	19.88%
Society	84.96%	76.95%	84.96%	73.99%	80.12%

Lawrence et al. Injury Mean Costs

All Cases	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

Figure 4.3. Classification and Monetization of WAP Prevented Injuries

US Household Income ≤ 150% Poverty

HO Insurance?	Households	Percent
Yes	10,464,465	63.46%
No	6,026,219	36.54%
Total	16,490,684	100.00%

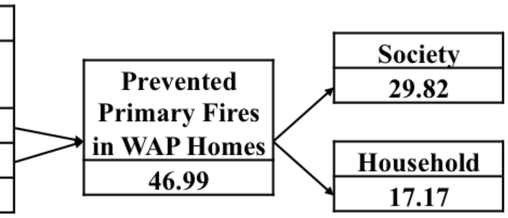


Figure 4.4. Division of WAP Prevented Primary Fires by Beneficiary

Table 4.24. Monetization of WAP Prevented Property Loss

Beneficiary	Prevented Fires	Average Cost	Total Cost
Societal	29.82	$29,341	$874,843
Household	17.17		$503,799
Total	46.99		$1,378,643

Table 4.25. Summary Frequency and Monetization of Various Prevented Fire Damages

Damage	Frequency	Household	Society	Total
WAP Fires	46.99	$503,800	$874,843	$1,378,643
WAP FF Deaths	0.0022	$0	$16,791	$16,791
WAP Other Deaths	0.70	$0	$5,278,798	$5,278,798
WAP FF Injuries	4.64	$0	$27,377	$27,377
WAP Other Injuries	1.64	$1,563	$8,130	$9,693
Total	-	$505,363	$6,205,939	$6,711,302

Table 4.26. Monetization of Benefits Attributable to Fire Prevention

Beneficiary	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 10 Years	PV Per Unit Benefit Over 10 Years
Households	$505,363	$6	$5,025,946	$63
Society	$6,205,939	$77	$61,719,426	$768
Total	$6,711,302	$84	$66,745,373	$831

Uncertainty Considerations and Further Research

Accuracy Assessment: Considering research and conventional wisdom on individual measures commonly installed in WAP homes, it is logical that WAP would contribute to a reduction in fire frequency, intensity, and subsequent damages. In spite of very limited research and available data regarding weatherization's role in fire prevention, this study followed several methods supported by literature as well as more innovative techniques. Though this lack of data required several assumptions, much care was taken at each step in order to err on the side of making conservative estimates. The major sources of uncertainty in these results are the fire risks for homes pre-weatherization and post-weatherization. As previously discussed, the Occupant Survey (and perhaps surveys as a whole) may not be adequate for describing fire risk among the WAP population, as its size and scope inhibit proper representation of frequency and severity. Consequently, pre-treatment risk was estimated by using population counts and averages to weight large amounts of fire data. Other than structure type, the 150 percent poverty threshold was the major factor used to represent the WAP population. While this shows a significant difference in fire frequency from the general population, actual WAP households may differ in other ways that would affect fire risk. WAP's higher populations of elderly and disabled persons could correspond to increased injury rates, and older homes are associated with increased fire frequency. On the other hand, homes in extreme disrepair and thus with high fire risk, may be deferred from receiving WAP services. Literature on fire and household income has shown that fire rates as well as fire injury rates are higher among households with lower income (Istre, et al. 2001; Shai 2006). This study weighted fire rates on household income but did not create separate weights for injuries and other damages. Such considerations went beyond the scope of this study but should be examined in future research.

In regards to estimating fire prevention, no research has been conducted that definitively maps weatherization measures, either singly or in combination, to the reduction of fire risks. The methodology developed above addresses this lack of research with a reasoned approach that qualitatively maps measures to fire risk data compiled nationally. Because these data come from two disparate sources as well as the inherent complexity of fire ignition and spread, there is no perfect method to match weatherization measures with contributors to fire.[89] Based on these considerations the monetization of fire prevention attributable to WAP is placed in Tier 3.

4.2.3 Reduced Thermal Stress on Occupants

Thermal stress on humans caused by extreme indoor thermal conditions (i.e. temperature, humidity, drafts) can have significant adverse effects on health and mortality. It is of the utmost importance that the benefit of weatherization with regard to reducing thermal stress on an occupant is recognized.

Hyperthermia, or overheating of the body, occurs when an individual's body produces or absorbs more heat than it dissipates. Health conditions associated with hyperthermia are heat exhaustion and heat stroke. Heat exhaustion can occur after an individual is exposed to high temperatures for several days and has become dehydrated. Without proper intervention, heat exhaustion can progress to heat stroke, which can damage the brain and other vital organs, and even cause death. Heat stroke is an extreme medical emergency requiring aggressive cooling measures and hospitalization for support (National Institute of Health (NIH) 2012).

Hyperthermia is strongly related to the heat stress index, which is a measurement of how hot an individual feels when the effects of relative humidity and air temperature are combined. A relative humidity of 60% or more hampers sweat evaporation, which hinders a body's ability to cool itself. The risk of heat-related illness dramatically increases when the heat index climbs to 90 degrees or more (NIH 2012).

In contrast, hypothermia is defined as a condition in which the core body temperature is less than 95^{o} F and occurs when the body's temperature regulation is overwhelmed by a cold environment. When one's body temperature drops, the heart, nervous system and other organs are not able to work correctly. Left untreated, hypothermia can eventually lead to heart and respiratory system failure and in extreme cases death. Exposure to extreme cold temperatures does not necessarily lead to hypothermia but can result in other severe medical conditions requiring medical assistance; such as, frostnip, frostbite, trench foot, and chilblains (CDC 2005).

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

WAP 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 excessive drafts in the home; alternatively, weatherization can address inadequate cooling systems and/or ventilation in the home to minimize heat-related illnesses.

[89] Before the current methodology was adopted, two different approaches attempted to connect NFIRS and DF2 quantitatively. Both matched NFIRS and DF2 using dummy variables similar to those in the final estimation. One methodology assigned each variable risk index values, using a home's aggregated score to model WAP's role in fire prevention. The other methodology determined the probabilities of each possible combination of those dummy variables and matched NFIRS cases and DF2 cases accordingly. However, these approaches were not used as a result of excessive assumptions and limited data.

Non-energy benefits from weatherization associated with reduction of thermal stress within the home:

The baseline and follow up national occupant survey[90] 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 that the number of times that occupants were required to seek medical attention due to exposure to extreme temperatures inside their home was reduced from the first administration of the survey to the second. Tables 4.27 and 4.28 indicate the reduction by percentages for both the treatment and comparison groups.[91] The average change in the treatment group pre- and post-weatherization plus the average change in treatment group pre-weatherization and the comparison group 1 (one year post-weatherization) (See Equation 1) yields a decreased rate of seeking medical attention of 1.4% for cold-related illnesses and 1.1% for heat-related illnesses. One could argue that regardless of the incremental drop in rates of occurrence within this particular sample, these results have major implications. It should be noted that these results could be underestimated because it was assumed that only one person per household is impacted by extreme temperatures and results for any one year could be quite sensitive to extreme winter and summer weather events.

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

Table 4.27. Reduction in Medical Care Needs due to Cold-related Illnesses Post-Weatherization

Cold-related Illnesses	Frequency	Percentage
# of Occurrences, Treatment (Pre- WX)	21	3.2%
# of Occurrences, Treatment (Post-Wx)	6	1.5%
# of Occurrences, Comparison 1	17	2.1%
Decreased Rate of Occurrence		**1.4%**

[90] For detailed information on the national occupant survey, refer to the Occupant Survey Report; Carroll, D. et al. (2014a).

[91] For exposure to extreme cold conditions, the statistical significance between the means between the treatment group and comparison group in first survey period is 0.211 and in the second survey period 0.665. The statistical difference between the means of the treatment group between the first survey and the second is 0.098 and between the comparison group means is 0.228. For exposure to extreme hot conditions, the statistical significance between the means between the treatment group and comparison group in first survey period is 0.058 and in the second survey period 0.262. The statistical different between the means of the treatment group between the first survey and the second is 0.318 and between the comparison group means is 0.470.

Table 4.28. Reduction in Medical Care Needs due to Heat-related Illnesses Post-Weatherization

Heat-related Illnesses	Frequency	Percentage
# of Occurrences, Treatment (Pre- WX)	16	2.4%
# of Occurrences, Treatment (Post- WX)	6	1.5%
# of Occurrences, Comparison 1	9	1.1%
Decreased Rate of Occurrence		**1.1%**

A sub-sample of the occupant survey respondents reported that their weatherization service was deferred (postponed); these responses are not included in the above analyses.[92] However, it is worth noting that 6.6% of this sub-sample reported seeking medical attention because their home was too cold and 3.4% from being too hot. This population is especially high-risk due to their housing being in such a state of disrepair that weatherization is not practical or possible.[93] Oft times these occupants cannot afford the necessary repairs to be able to move forward with weatherization services.

Interesting findings are revealed when this same sub-group is broken down into climate regions (see Table 4.29); 13.3% of those respondents residing in a hot-humid region stated they sought medical attention for their home being too *cold*, and 5.4% of those within the very cold climate zone reported seeking medical care for being too *hot.* These findings seem to highlight specific needs of this demographic as they relate to regional differences in housing stock (e.g., construction type and vintage). If this model was to be replicated and the study oversampled a very cold (and possibly included large multifamily units) or hot-humid climate zone one could argue that findings would be even higher.

Table 4.29. Percent of Respondents in Deferral Sub-sample that Sought Medical Attention for Home Being Either Too Hot or Too Cold

Climate Zone	Too cold	Too hot
Hot-Humid (n=30)	13.3%	10%
Very Cold (n=56)	8.9%	5.4%
Cold (n=143)	3.5%	2.1%
Moderate (n=53)	9.4%	1.9%

This high-risk population will only become higher at risk as temperatures are rising and heat wave frequency and duration continue to increase due to climate change.

To further support the significance of these findings, another study conducted through the WAP evaluation, the Indoor Environmental Quality Study[94,] consisted of an Occupant Survey (pre-weatherization only) as well; 5% of the respondents stated they sought medical attention for being too cold and 2.2% for being too hot. These frequencies are in line with the findings from the national occupant survey results.

[92] This sub-group was part of the treatment group (pre-weatherization) for the baseline survey that were told after the audit that weatherization needed to be deferred (n=290). For the follow-up survey, 122 of those were re-contacted and reported that they still had not received weatherization.
[93] See Deferral Study report, Rose et al. (2014), for more information on deferral policy within WAP.
[94] See Pigg, et al. (2013)

In order to monetize these non-energy benefits it was required to establish the average costs for three alternative sources of medical treatment[95] as the survey question did not allow for a specification of what type of medical attention was needed; hospitalization, ED visit or a physician office visit.

The hospitalization and ED costs for treatment for cold and heat-related illnesses associated with thermal stress 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).[96] The costs for a physician office visit were retrieved from a collection of databases sponsored again by AHRQ referred to as the Healthcare Cost and Utilization Project (HCUP).[97]

A percentage, based on the frequency of type of medical services sought (see Inputs on next page), was then calculated in order to proportion costs.[98] This allowed for a total cost savings for the WAP Program (first year), as well as per WAP household, to be calculated.

Societal Benefits vs. Household Benefits

The total cost savings of weatherization was further broken down and grouped as either a societal benefit or a household benefit.

Insurance coverage can vary among the WAP eligible demographic, i.e. Medicare, Medicaid, private insurance or uninsured. If an occupant was covered by Medicaid or Medicare, the cost savings in this context is categorized as a societal benefit as opposed to a household benefit since there would be no out-of-pocket expenses accrued. If the occupant was covered by a private insurance company, the benefits could be applied to either society and/or household. The societal benefits would be the costs that would have been covered by insurance and household benefits would be the avoided out-of-pocket costs (i.e. copayments, deductibles.) Furthermore, for an uninsured occupant, all out-of-pocket costs would be categorized as a household benefit.[99]

In order to monetize the non-energy benefits by these two groups, a percentage was calculated from the breakdown of average yearly out-of-pocket costs and average yearly insurance costs per type of medical treatment sought for conditions associated with exposure to both extreme hot and extreme cold temperatures (see Inputs on next page).[100]

[95] Average medical costs for treatment of cold-related illnesses: Hospitalization = $9,455; ED = $552; Physician Office Visit = $136. Average medical costs for treatment of heat-related illnesses: Hospitalization = $5,802; ED = $624; Physician Office Visit = $136

[96] Data generated from the survey can be found on the following website: http://meps.ahrq.gov/mepsweb/

[97] 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.

[98] Data used to calculate this ratio was collected from the MEPS database.

[99] Out-of pocket medical expenses for many families, including those with incomes higher than the WAP eligible population, are at times unable to be paid. If these costs are not eventually settled through a collection service, this may result in unpaid medical bills that may eventually become a societal debt. For the purposes of this study, avoided out-of-pocket medical expenses will still be considered a household benefit as these expenses are ultimately the responsibility of the patient; although we recognize that this could be considered speculative. The complexity of determining the percentage of these costs that would become a societal burden is beyond the scope of this study.

[100] Data used to calculate this ratio was also collected from the MEPS database. However, it should be noted that the sample size for this data is limited. N = 82

Variables and Equations (used to calculate both hot and cold temperature exposure):

- a = hospitalization, b = ED visit, c = physician office visit: Type of treatment

- N (a, b, c) = Number of occurrences of medical treatment avoided due to WAP, by type of treatment:

  *N (a, b, c) = [(number of weatherized units completed in PY 2008) * (decreased rate of seeking medical care) * (% of type of medical treatment (a, b, c)]*

- B_H = Household Benefit per type of treatment (for WAP in PY 2008)

  B_H *= [N (a, b, c) * (average total out-of-pocket medical costs paid by households)]*

- B_S = Societal Benefit per type of treatment (for WAP in PY 2008)

  B_S *= [N (a, b, c) * (average total medical costs paid by insurance companies)]*

- TPB = Total Program Benefit (for WAP in PY 2008):

  $$TPB = [B_S + B_H]$$

- TBU = Total Benefit per Unit treated in PY 2008

  TBU = [TPB / (number of weatherized units completed in PY 2008]

- PV=TPB 10 year Present Value for 2013[101]

  PV = (0.001, 10, TPB) -1*

Inputs:

- Number of weatherized units completed in PY 2008 = 80,352
  (Source: S1 – State Program Information Survey)

- Reported decreased rate of seeking medical care in PY 2008: cold exposure, 1.4%; heat exposure, 1.1% (Source: S4 – National Occupant Survey)

- For treatment of cold-related illnesses in PY 2008, percentage requiring:
  Hospitalizations = 10.0%, ED visits = 40.0%, Physician office visits = 50.0%

- For treatment of heat-related illnesses in PY 2008, percentage requiring:
  Hospitalizations = 4%, ED visits = 11.5%, Physician office visits = 84.5%

- Total out-of-pocket (household) medical costs (mean) paid in PY 2008 for treatment of cold-related illnesses:
  Hospitalization = $87,428; ED = $53,918; Physician Office Visit = $12,509

[101] The ten-year real treasury interest rate for 2013 (0.1%) from Office of Management and Budget (OMB) was used to calculate the PV.

- Total societal (insurance) medical costs (mean) paid in PY 2008 for treatment of cold-related illnesses:
  Hospitalization = $977,146; ED = $193,740; Physician Office Visit = $64,339

- Total out-of-pocket (household) medical costs (mean) paid in PY 2008 for treatment of heat-related illnesses:
  Hospitalization = $15,944; ED = $104,030; Physician Office Visit = $2,263

- Total societal (insurance) medical costs (mean) paid in PY 2008 for treatment of heat-related illnesses:
  Hospitalization = $189,228; ED = $361,802; Physician Office Visit = $11,640

- PV Benefit over 10 years: .1%

Tables 4.30 and 4.31 contain the estimates for benefits attributable to reducing thermal stress, cold-related and heat-related respectively, to households and society.

Table 4.30. Monetization of Benefits Attributable to Reducing the Incidence of Cold-Related Illnesses

	First Year Per Unit Benefit	PV Per Unit Benefit Over Ten Years	First Year Program Benefit	PV Program Benefit Over 10 years
Households	$1.91	$19.04	$153,854	$1,530,119
Society	$15.37	$152.88	$1,235,225	$12,284,587
Total	**$17.29**	**$171.93**	**$1,389,079**	**$13,814,706**

Table 4.31. Monetization of Benefits Attributable to Reducing the Incidence of Heat-Related Illnesses

	First Year Per Unit Benefit	PV Per Unit Benefit Over Ten Years	First Year Program Benefit	PV Program Benefit Over 10 years
Households	$1.52	$15.13	$122,236	$1,215,668
Society	$7.00	$69.64	$562,669	$5,595,870
Total	**$8.52**	**$84.77**	**$684,905**	**$6,811,538**

Thermal Stress and Mortality

As mentioned previously, exposure to extreme temperatures for a prolonged amount of time can result in death. Nationwide frequencies of deaths after hospitalization due to thermal stress can be found in the MEPS database used above. It is assumed that the same proportion of deaths following hospitalizations for the WAP population is the same as for the U.S. population. Equations utilized for monetizing cost savings based on the numbers of deaths potentially prevented by weatherization are as follows:

- Number of lives saved = [(% of hospitalizations resulting in deaths (U.S. population) * (# of hospitalizations prevented by WAP in PY 2008)]

- Benefit = # of lives saved by WAP * Value of Human Life

The inputs used in these equations are as follows:

- # of hospitalizations (U.S., 2008) - 3,410 (cold); 3,387 (hot)
- # of deaths following hospitalizations (U.S., 2008) – 122 (cold); 81 (hot)
- % of hospitalizations resulting in deaths (U.S., 2008) – 4% (cold); 2% (hot)
- # of hospitalizations prevented (WAP, PY 2008) – 113 (cold); 35 (hot)
- # of lives saved (WAP, PY 2008) - 4 (cold); 1 (hot)
- Value of Human Life - $7,500,000

Table 4.32 presents inputs utilized to calculate the monetary benefit attributable to saving a life from exposure to extreme thermal conditions.

Table 4.32. Monetary Benefits Attributable to Saving a Life from Exposure to Extreme Thermal Conditions

	# of hospitalizations (U.S., 2008)	# of deaths following hospitalizations (U.S., 2008)	% of hospitalizations resulting in deaths (U.S., 2008)	# of hospitalizations prevented - (WAP population, 2008)	# of lives saved (WAP, 2008)	Value of Human Life
Cold-related	3,410	122	4%	113	4	$7.5 M
Heat-related	3,387	81	2%	35	1	$7.5 M

Table 4.33a and 4.33b presents total cost savings including office visits, ED visits, hospitalizations and deaths for cold and heat exposure respectively. The benefit attributable to saving a human life is considered a societal benefit.

Table 4.33a. Total Cost Savings Attributable to Reducing the Incidence of Cold-Related Illnesses and Deaths

	First Year Per Unit Benefit	PV Per Unit Benefit Over Ten Years	First Year Program Benefit	PV Program Benefit Over 10 years
Households	$1.91	$19.04	$153,855	$1,530,119
Society	$391.35	$3,892.09	$31,446,005	$312,737,416
Total	**$393.26**	**$3,911.14**	**$31,599,860**	**$314,267,535**

Table 4.33b. Total Cost Savings Attributable to Reducing the Incidence of Heat-Related Illnesses and Deaths

	First Year Per Unit Benefit	PV Per Unit Benefit Over Ten Years	First Year Program Benefit	PV Program Benefit Over 10 years
Households	$1.52	$15.13	$122,236	$1,215,668
Society	$85.93	$854.63	$6,904,985	$68,671,586
Total	**$87.45**	**$869.76**	**$7,027,221**	**$69,887,254**

Accuracy Assessment: It is logical to contend that weatherization can reduce thermal stress on humans caused by exposure to extreme indoor temperatures. It was observed through the national occupant survey that reported incidences of seeking medical treatment from heat and cold-related illnesses were in fact reduced post-weatherization. To establish the percentage of reduction the difference of means between pre-post treatment and pre-treatment and post-control were used. We are confident that the pre-treatment frequencies are accurate and representative and therefore can be used as a proxy for the pre-comparison group frequency.

Since the occupant survey question did not differentiate which type of medical attention was required (i.e. hospitalization, emergency department or physician office); it was necessary to utilize data for the general US population to establish the proportion of types of treatment sought for heat and cold-related illnesses. For the monetization of thermal stress related fatalities the survey did not ask if a fatality within the household occurred due to extreme thermal stress, only if medical attention was sought. In addition, if the head of household died then a follow up survey could not be conducted with that individual. Therefore, the number of deaths following hospitalizations for these conditions per year were pulled from the national medical data bases and not based on the occupant survey data. Generalizing this proportion of deaths from the national population to the WAP population is a quite reasonable assumption since this population is at higher risk than the general population. Estimates are on the conservative side due to the assumption that only one person per household was impacted. Furthermore, the data from the national medical data base was from the year that the occupant survey was administered. For these reasons, the monetized estimate from reduced incidences of medical attention and fatalities due to thermal stress is placed in Tier 1.

4.2.4 Reduced Asthma-Related Ed Visits, Hospitalizations, Other Direct Medical Costs, And Indirect Costs

Understanding the asthma-related health benefits of weatherization and healthy homes interventions is of upmost importance as asthma continues to be the most common chronic pediatric disease and the leading cause of pediatric hospitalizations disproportionately impacting children in poverty, children of Hispanic and African American ethnicity, and those residing in urban environments (Rastogi 2013; Castro 2003). A recent study attempted to determine key predicting factors for high healthcare utilization or "super-utilizers"[102] among Hispanic and African American children (Rastogi 2013). The study revealed that caregiver knowledge alone of asthma pathophysiology, control, and treatment does not adequately prevent high healthcare utilization. Participants in the study reported feelings of stress and helplessness, an inability to implement the actions learned, and on-going use of the ED. Although the authors of the study report that high healthcare utilizers had fewer ED visits post "targeted educational interventions," many of the asthma trigger reduction measures remain beyond the scope of the household to complete on

[102] The Center for Medicaid and CHIP Services (CMCS) defines super-utilizers as those "beneficiaries of complex, unaddressed health issues and a history of frequent encounters with health care providers."

their own (Rastogi 2013). We can begin to attribute the benefits of asthma trigger reductions inside the home to WAP through household self-reported changes in symptoms and use of urgent care facilities.

As discussed in Section 3.4, due to the diverging sample characteristics between the whole asthma sample and the same-household samples (most likely attributed to the small sample size of the same-household sample), and due to the diverging characteristics between the whole sample treatment and comparison groups, changes in responses pertaining to urgent care utilization due to asthma will be monetized using the whole asthma sample treatment group pre- and post-weatherization. Tables 4.34 and 4.35 presents the final descriptive frequencies to be used for the monetization of these benefits attributed to 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?*__________________

Table 4.34. Reduction in Asthma Related ED Visits for All Respondents Reporting Current Diagnosis of Asthma.

% of Respondents Reporting Visit to ED due to asthma	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**

Table 4.35. Reduction in Asthma Related Hospitalizations for All Respondents Reporting Current Diagnosis of Asthma

% of Respondents Reporting Hospitalization due to asthma	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) * (reduction in ED visits)* (frequency of re-admittance (adults and children)) * (average ED costs (adults and children))

The inputs used in this equation are as follows:

- Number of Persons Served by WAP in PY 2008 – 199,825 (source: S4 – National Occupant Survey mean number of persons per household (2.487) * total households served in PY 2008 (80,352))

- Number of adults and children in WAP households– 119,901 adults; 79,934 children (source: S4 – National Occupant Survey; Ratio of adults to children reported was used to proportion the total population served by WAP in PY 2008)

- Percent of adults in WAP households with asthma – 16.8% (source: S4 – National Occupant Survey; average of phase 1 and phase 2 surveys)

- Percent of children in WAP households with asthma – 16% for children in African American households; 10.1% for children in non-African American households (source: CDC 2006-2008 national asthma rates; http://www.cdc.gov/mmwr/preview/mmwrhtml/su6001a18.htm)

- Reduction in ED Visits– 11.5% (source: S4 – National Occupant Survey; Treatment Group Whole Asthma Sample)

- Frequency of re-admittance to ED; all persons with asthma– 31.3% (source: http://www.hcup-us.ahrq.gov/reports/statbriefs/sb90.jsp ; http://www.cdc.gov/pcd/issues/2004/apr/03_0009.htm ; http://www.aaaai.org/about-the-aaaai/newsroom/asthma-statistics.aspx)

- Average costs for ED visit for asthma; all persons with asthma– $512 (source: MEPS)

- Total WAP households PY 2008 – 80,352 (source: S1 – National State Program Information Survey)

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))

The inputs used in this equation are as follows:

- Number of Persons Served by WAP in PY 2008 – 199,825 (source: S4 – National Occupant Survey mean number of persons per household (2.487) * total households served in PY 2008 (80,352))

- Number of adults and children in WAP households– 119,901 adults; 79,934 children (source: S4 – National Occupant Survey; Ratio of adults to children reported was used to proportion the total population served by WAP in PY 2008)

- Percent of adults in WAP households with asthma – 16.8% (source: S4 – National Occupant Survey; average of phase 1 and phase 2 surveys)

- Percent of children in WAP households with asthma – 16% for children in African American households; 10.1% for children in non-African American households (source: CDC 2006-2008 national asthma rates; http://www.cdc.gov/mmwr/preview/mmwrhtml/su6001a18.htm)

- Reduction in hospitalizations – 3.1% (source: S4 – National Occupant Survey; Treatment Group Whole Asthma Sample)

- Frequency of re-admittance to hospital; adults– 27.3% (source: http://www.hcup-us.ahrq.gov/reports/statbriefs/sb90.jsp)

- Frequency of re-admittance to hospital; children– 22.9% (source: http://www.hcup-us.ahrq.gov/reports/statbriefs/sb90.jsp)

- Average costs for hospitalization per adult +18 years of age– $6,341(source: MEPS)
- Average costs for hospitalization per child– $3,616 (source: HCUP)
- Total WAP households PY 2008 – 80,352 (source: S1 – National State Program Information Survey)

In addition to averted medical costs associated with hospitalization and ED visits due to asthma, there is 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 (reduced prescribed medicines, office and clinic visits, and hospital outpatient) and indirect costs (reduced housekeeping loss, loss of work and school productivity, and restricted activity). The data mentioned in this report suggests that weatherization provided through WAP is a significant predicting variable for 1/3 of asthma cases requiring ED visits; if homes are weatherized, persons with asthma are less likely to visit the ED.

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 determine the percentage of respondents identified as "high-cost" asthma patients pre-weatherization, but then identified as "low-cost" asthma patients post-weatherization. The literature suggests that high-cost asthma patients account for two-thirds of the ED visits and hospitalizations due to asthma in the US (Smith et al. 1997). 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. The results presented in Table 4.36 indicate that the large majority of those reporting use of urgent care facilities do fall into the high-cost patient category, thereby validating the methodology employed. Table 4.37 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.

Table 4.36. Urgent Care (ED or Hospitalization) due to Asthma For High- and Low-Cost Patients

% of Respondents Reporting Urgent Care (ED or Hospitalization) due to asthma by Group and by Sample and by High or Low-Cost Patient	**Low-Cost Patient**	**High-Cost Patient**
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=92)	5.6%	94.4%
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=46)	16.7%	83.3%

Table 4.37. Reduction in High-Cost Patients

% of Respondents Identified as High-Cost Asthma Patient * by Group and by Sample	**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))

The inputs used in this equation are as follows:

- Number of Persons Served by WAP in PY 2008 – 199,825 (source: S4 – National Occupant Survey mean number of persons per household (2.474) * total households served in PY 2008 (80,352))

- Number of adults and children in WAP households (source: S4 – National Occupant Survey; Ratio of adults to children reported was used to proportion the total population served by WAP in PY 2008)

- Percent of adults in WAP households with asthma – 16.8% (source: S4 – National Occupant Survey)

- Percent of children in WAP households with asthma – 16.8% for children in African American households; 10.1% for children in non-African American households (source: CDC 2006-2008 national asthma rates; http://www.cdc.gov/mmwr/preview/mmwrhtml/su6001a18.htm)

- Reduction of high-cost patients moving from symptoms <3months ago to >3months ago– 11.8% (source: S4 – National Occupant Survey)

- Other direct medical costs and indirect costs associated with high-cost asthma patients adjusted for inflation– $2,302 (total annual direct and indirect costs for high cost asthma patients=$5566. Of this 54% is attributed to ED/In-patient hospitalization costs. After these costs were extracted, the total costs for the purposes of measuring cost savings for other direct/indirect costs = $2561. Applying the same methodology, total costs for low-cost patients=$259 for a cost savings if a patient went from high to low cost (n=3428) of $2,302. Source: Smith et al. 1997)

- Total WAP households PY 2008 – 80,352 (S1 – National State Program Information Survey)

Spread over all weatherization jobs in PY 2008, the average first year societal benefit per unit from reduced ED visits, hospitalizations, other direct medical costs, and indirect costs is $187 and the PV is $1,852. The total first year societal benefit is $15M and the PV over ten years is $151M.[103] Spread over all weatherization jobs in PY 2008, the average first year household benefit per unit from averted direct medical and indirect costs as a result of reduced exposed to multiple environmental asthma triggers is $16 and the PV is $157. The total household benefit in the first year is $1.3M and the PV of this benefit over ten years is $13M. The total non-energy benefits associated with asthma attributable to WAP per unit is $202 and the PV per unit is $2,009. Table 4.38 summarizes these results.

[103] Societal benefits included 98.8% of the urgent care costs saved from ED visits and hospitalizations due to asthma (HCUP/MEPS) and 85.2% of the total costs saved from high-cost asthma patients becoming low-cost asthma patients (Smith et al. 1997)

Table 4.38. Monetized Benefits Attributable to Reduction in Asthma Symptoms

	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 10 years	PV Per Unit Benefit Over Ten Years
Households	$1,269,965.20	$15.75	$12,630,082.45	$156.66
Ratepayers	0	0	0	0
Society	$15,133.735.38	$186.25	$150,508,316.98	$1,852.28
Total	$16,403,700.58	$202.00	$163,138,399.42	$2,008.93

Accuracy Assessment: It is logical to contend that weatherization can reduce environmental asthma triggers in the home and thereby reducing the use of urgent care facilities, other direct medical expenses and indirect expense associated with asthma. It was observed through the national occupant survey that reported incidences of seeking urgent medical treatment through the ED and hospitals from asthma were reduced post-weatherization. To establish the percentage of reduction differences in percentage in affirmative responses from pre-weatherization to post-weatherization in the treatment group were used. We are confident that the pre-treatment frequencies are accurate and representative and therefore can be used for this determination. Cost data for ED visits and hospitalizations for asthma were pulled from a national medical data base.

Since the occupant survey did not offer adequate data for the determination of changes in other direct medical expenditures and indirect expenses, a methodology was employed based on the literature and survey responses related to frequency of asthma symptoms were input. These data describing the proportion of total costs associated with asthma (direct and indirect) were dated (1997). No such national study breaking out these costs with recent medical data is known survey questions did not inquire about other household members in the first phase of the survey (which was the only phase capturing the pre-weatherized environment and was the phase with the best response rate) it was necessary to; use the average household size and average number of children per household to estimate the number of children with asthma in the WAP population; utilize data for the general US asthma population to establish the national average of children in poverty with asthma and by demographic. For these reasons, the monetized estimate from reduced asthma is placed in Tier 1.

4.2.5 Improved Worker Productivity Due To Improvements in Sleep

It has been found that lack of sleep can lead to decreased productivity at work. It is possible that by making homes more comfortable, weatherization could help improve the sleep of Program recipients (See Section 3.2). To explore this societal non-energy benefit, this question was included in the national occupant survey:

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

or sleep?

The percentage of treatment group respondents who reported sleep/rest problems the previous month was 66.0% pre-weatherization and 29.1% post-weatherization. The results for the comparison group were

60.0% and 32.9%, respectively.[104] Averaging the change between the treatment group pre-weatherization and the comparison group in the first survey period and the treatment group pre- and post-weatherization yields an estimated change of 21.4%. This non-energy benefit was quantified as follows:

- Total Program Benefit = (number of Wx Jobs completed in PY 2008) * (percent increase in respondents reporting no rest or sleep problems) * (cost per year per employee in productivity losses due to sleep problems) * (percent of respondents employed full-time)

The inputs used in this equation are as follows:

- Number of Wx Jobs completed in PY 2008: 80,352 (source: S1 – State Program Information Survey)

- Percent decrease in respondents reporting no sleep problems: 4.6% (source: S4 -- National Occupant Survey)

- Cost in lost productivity per year for employees with sleep problems: $2500 (Source: http://www.businessinsider.com/workers-lack-of-sleep-costs-employers-millions-of-dollars-each-year-2011-1; http://www.ncbi.nlm.nih.gov/pubmed/20042880)

- Percent respondents employed full-time: 34% (Source: S4 -- National Occupant Survey)

Using the above equation and these inputs, the first year benefit to society $3M. Per unit the benefit is $39.14. The PV for the Program to society over ten years is $31M. The PV per unit over a ten year period is $389.26. Table 4.39 summarizes these benefits.[105]

Table 4.39. Monetized Benefits Attributable to Increased Work Productivity

	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 10 years	PV Per Unit Benefit Over Ten Years
Households	0	0	0	0
Society	$14,650,178	$182.33	$145,699,236	$1,813
Total	$14,650,178	$182.33	$145,699,236	$1,813

Accuracy Assessment: It is logical to contend that weatherization can lead to improvements in sleep/rest given that weatherization can improve thermal comfort, reduce the intrusion of noise from outside, and reduce mental stress about household budgets, for example. It was observed through the national occupant survey that overall more respondents experienced better sleep and rest post-weatherization. It was not observed, though, to what degree employed survey respondents' productivity increased at work. It was also not observed to what the economic value of any productivity increases were. A study found in the literature was used to estimate the monetizable benefit and to value its economic value. The study was well done but its results were generalized to the broader type of jobs held by employed persons who reside in WAP weatherized homes. For these reasons, this NEB is placed in Tier 3.

[104] The statistical significance between the means between the treatment group and comparison group in first survey period is 0.018 and in the second survey period 0.003. The statistical different between the means of the treatment group between the first survey and the second is 0.000 and between the comparison group means is 0.00.

[105] It should be noted that this benefit estimation may be underestimated because only households with an employed respondent and only one employed person per household were included in this analysis.

4.2.6 Improved Household Work Productivity Due To Improvements in Sleep

Economists have long recognized that the time invested by individuals in doing various housework-related tasks has a value to society. It has been found that lack of sleep can lead to decreased productivity at work. One can also hypothesize, then, that lack of sleep can lead to decreased productivity in housework. It is possible that by making homes more comfortable, weatherization could help improve the sleep of Program recipients (See Section 3.2). To explore this societal non-energy benefit, this question was included in the national occupant survey:

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

The percentage of treatment group respondents who reported sleep/rest problems the previous month pre-weatherization was 66.0% and 29.1% post-weatherization. The results for the comparison group were 60.0% and 32.9%, respectively.[106] Averaging the change between the treatment group pre-weatherization and the comparison group in the first survey period and the treatment group pre- and post-weatherization yields an estimated change of 21.4%. This non-energy benefit was quantified as follows:

- Total Program Benefit = (number of Wx Jobs completed in PY 2008) * (percent increase in respondents reporting no rest or sleep problems) * (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:

- Number of Wx Jobs completed in PY 2008: 80,352 (source: S1 – State Program Information Survey)

- Percent increase in respondents reporting no sleep problems: 4.6% (source: S4 -- National Occupant Survey)

- Cost in lost productivity per year for employees with sleep problems: $2500 (Source: http://www.businessinsider.com/workers-lack-of-sleep-costs-employers-millions-of-dollars-each-year-2011-1)

- Average hourly wage rate for general housekeeping: $10.49 http://www.bls.gov/oes/current/oes372012.htm

- Average hours per week on housework: 21.5 (http://www.bls.gov/opub/mlr/2009/07/art3full.pdf)

Using the above equation and these inputs, the first year benefit to households is $2.3M. Per unit the benefit is $28.69. The PV for the Program to households over ten years is $23M. The PV per unit over a ten year period is $285.38. Table 4.40 summarizes these benefits.[107]

[106] The statistical significance between the means between the treatment group and comparison group in first survey period is 0.018 and in the second survey period 0.003. The statistical different between the means of the treatment group between the first survey and the second is 0.000 and between the comparison group means is 0.000.

[107] It should be noted that this benefit estimation is underestimated because only one respondent per weatherized home is included in this analysis.

Table 4.40. Monetized Benefits Attributable to Increased Housework Productivity

	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 10 years	PV Per Unit Benefit Over Ten Years
Households	$10,740,521	$133.67	$106,816,837	$1,329
Society				
Total	$10,740,521	$133.67	$106,816,837	$1,329

Accuracy Assessment: It is logical to contend that weatherization can lead to improvements in sleep/rest given that weatherization can improve thermal comfort, reduce the intrusion of noise from outside, and reduce mental stress about household budgets, for example. It was observed through the national occupant survey that overall more respondents experienced better sleep and rest post-weatherization. It was not observed, though, to what degree employed survey respondents' productivity increased at home. It was also not observed to what the economic value of any productivity increases were. A study found in the literature was used to estimate the monetizable benefit to the private sector and to value its economic value. The study was well done but its results were generalized to the related to done in homes by persons who reside in WAP weatherized homes. For these reasons, this NEB is placed in Tier 3.

4.2.7 Fewer Missed Days at Work

Weatherization makes homes more comfortable, healthy, and safe. One can argue that these outcomes could lead to an additional benefit, fewer missed days at work. The national occupant survey posed these two questions to the respondent:

In the past 12 months, about how many days of work did you (or the primary wage earner) miss at a job or business because of illness or injury? _____________

In the past 12 months, about how many days of work did you (or the primary wage earner) miss because of illness or injury of another household member? ______________

Table 4.41 represents the survey results.[108]

Table 4.41. Missed Days at Work – Pre- and Post-Weatherization

Days Missed Work Primary Wage Earner	Pre-Wx Treat	Post-Wx Treat	Post-Wx Comp 1	Post-Wx Comp 2
Own Illness/Injury	5.85	6.01	5.93	8.42
Other HHD Member Illness/Injury	1.82	1.03	1.33	2.43
Total Days Missed	7.67	7.04	7.26	10.85

Averaging the change between the treatment group pre-weatherization and the comparison group in the first survey period and the treatment group pre- and post-weatherization yields an estimated change of 0.52 fewer days missed work. The total non-energy benefit attributable to fewer missed days at work was monetized as follows:

[108] The statistical significance between the means between the treatment group and comparison group in first survey period is 0.817 and in the second survey period 0.163. The statistical different between the means of the treatment group between the first survey and the second is 0.730 and between the comparison group means is 0.146.

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

The household benefit is 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.

The inputs used in this equation are as follows:

- Number of Wx Jobs completed in PY 2008: 80,352 (source: S1 – State Program Information Survey)

- Percent of WAP households with an employed primary wage earner: 34% (source: S4 – National Occupant Survey)

- Reduction in missed days work: 0.52 days (source: S4 – National Occupant Survey)

- Average hourly wage: $14.32 (http://nlihc.org/oor/2013, average hourly wage for renter)

- Percent of low income workers without sick leave: 80% (source: http://www.nationalpartnership.org/site/PageServer?pagename=psd_toolkit_quickfacts)

Using the above equation and these inputs, first year national wage increase benefit is $1.6M. Over ten years, the total PV of this benefit is $16M. The average first year benefit to a household with an employed primary wage earner is $16.20. The PV over a ten year period is $161.15. Spread over all weatherization jobs in PY 2008, the average first year benefit per unit is $20.25 and the PV is $201.43. For those workers who do have sick leave, then a reduction of missed workdays would benefit their employers/society. Table 4.42 summarizes these results.[109]

Table 4.42. Monetization of Benefits Attributable to Fewer Missed Days at Work

	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 10 years	PV Per Unit Benefit Over Ten Years
Households	$1,301,972	$16.20	$12,948,405	$161.15
Society	$325,493	$4.05	$3,237,101	$40.29
Total	$1,627,466	$20.25	$16,185,507	$201.43

Accuracy Assessment: It is logical to contend that weatherization can lead to improvement in occupants' health. It is also logical to contend that improvements in occupants' health will allow employed occupants to miss fewer days of work. Numerous questions from the national occupant survey support the contention that occupants are healthier post-weatherization. Employed respondents were directly asked about missed days of work pre- and post-weatherization. Monetizing the value of not missing a day of work was straightforward using published hourly incomes of low-income workers. For these reasons, this NEB is placed in Tier 1.

[109] The estimate may under-valued because only one person per household was included in the analysis.

4.2.8 Reduced Need for High Interest, Short-Term Loans

The non-energy benefit potentially accruable to WAP addressed in this section is that households can apply energy cost savings and other income benefits attributable to weatherization to reduce their use of short-term, high interest loans, and the amount of money paid on interest per year. Survey respondents were 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

Table 4.43 presents the survey results by type of loan and frequency of their use pre- and post-weatherization. The rate of payday loan use by respondents pre-weatherization is about equal to the national rate of 5.5%.[110] The same is assumed for the other loan categories.[111] Averaging the change between the treatment group pre-weatherization and the comparison group in the first survey period and the treatment group pre- and post-weatherization yields an estimated change for each loan type that is found in the last row of Table 4.43.[112]

Table 4.43. Frequency of Use of Short-term, High Interest Loans by WAP Recipients (%)

	Payday		Tax Refund Anticipation		Car Title		Pawn Shop		Other types of short-term, high-interest	
	Pre-Wx	Post-Wx	Pre-Wx	Post-Wx	Pre-Wx	Post-Wx	Pre-Wx	Post-Wx	Pre-Wx	Post-Wx
Treatment Group	5.4	4.0	6.5	4.0	2.4	1.0	2.9	3.0	8.0	4.0
Comparison Group	3.9	3.0	4.0	2.0	1.7	2.0	2.4	2.0	4.5	3.0
Change		1.5		2.5		1.1		.2		3.8

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 4.44.

110 http://www.pewstates.org/research/featured-collections/payday-lending-in-america-85899405692 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

111 The statistical significance between the means for total loans use between the treatment group and comparison group in first survey period is 0.002 and in the second survey period 0.178. The statistical different between the means of the treatment group between the first survey and the second is 0.265 and between the comparison group means is 0.597.

112 Three of the eleven NEBs monetized herein have some relationship to household budget changes attributable to weatherization: reduced use of short-term, high-interest loans; better being able to afford prescriptions; and reduced need for food assistance. It needs to be pointed out that not all households will experience these benefits. Some may reduce their use of loans, others their need for food assistance. Some may not experience any budget changes or even negative changes from pre- to post-weatherization. 22% of treatment households reported an improvement in one of the three budget categories post-weatherization, 3.6% in two, and 0.3% in three. 11% reported a worse outcome in one budget category, 2% in two. On average, treatment households reported an improvement of 0.15 budget categories post-weatherization.

Table 4.44. Estimated Magnitudes of Annual Short-term, High-Interest Loans per Household

	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

In general, the total benefit was calculated using this formula:

Total Benefit = (total WAP jobs) * (percent reduction in households using short-term, high-interest loans) * (reduction in interest payments)

The inputs used in this equation are as follows:

- Number of Wx Jobs completed in PY 2008: 80352 (source: S1 – State Program Information Survey)

- Percent reduction in households using short-term, high-interest loans: See above (source: S4 -- National Occupant Survey)

- Average Loan: See above. Also 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[113]

- Average Interest Payment: See above. Also assumed that loan was paid back in one month with a 25% monthly interest rate.

Using the above equation and these inputs, the total first year benefit to society is $572,000. Per unit the benefit is $7.12. The PV benefit to society over ten years is $5.7M. The PV per unit over a ten-year period is $70.77. Table 4.45 summarizes these results.

Table 4.45. Monetized Benefits Attributable to Reducing Interest Payments on Short-Term, High Interest Loans

	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 10 years	PV Per Unit Benefit Over Ten Years
Households	$572,000	$7.12	$5,700,000	$70.77
Society				
Total	$572,000	$7.12	$5,700,000	$70.77

Accuracy Assessment: It is logical to contend that weatherization could have a positive enough impact on household budgets that some households that used high-interest, short-term loans pre-weatherization

[113] Less than 5% of respondent households make use of more than one type of these loans per year. It is a conservative assumption that households that do make use of one of these loan types only do so once a year.

could stop using these loans post-weatherization. It was observed through the national occupant survey that overall use of these loans reduced post-weatherization. It was not observed directly how much money households saved in interest charges post-weatherization. Various references of a range of quality were used to estimate annual loan amounts and interest charges. Many assumptions were needed to use these resources in this analysis. For these reasons, this NEB is placed in Tier 2.

4.2.9 Increased Ability to Afford Prescriptions

It is possible that the direct household income benefits attributable to WAP may allow some households to afford prescription medicines after weatherization. An important benefit to society for complying with physician directed prescriptions is a substantial reduction in hospitalization rates. To explore this societal non-energy benefit, this question was included in the national occupant survey:

During the past 12 months, was there any time your household members needed prescription medicines but didn't get them because you couldn't afford it?

Thirty-three percent of the treatment group households surveyed pre-weatherization reported not being able to afford prescription medicines, versus 22% post-weatherization, for a difference of 11%. The post-weatherization comparison group dropped from 24% to 21% from one period to the next.[114] Averaging the change between the treatment group pre-weatherization and the comparison group in the first survey period and the treatment group pre- and post-weatherization yields an estimated change of 10%. This non-energy benefit was quantified as follows:

- Benefit = (number of Wx Jobs completed in PY 2008) * (percent increase in WAP households being able to afford prescription medicines)* (annual cost to nation of patients not taking prescription medicines) / number of people who should be taking prescription medications in the US) * (1.0 - prescription use compliance rate))*.5 [115]

The inputs used in this equation are as follows:

- Number of Wx Jobs completed in PY 2008: 80352 (source: S1 – State Program Information Survey)

- Percent increase in households being able to afford prescription medications: 10% (source: S4 -- National Occupant Survey)

- Annual cost to nation of patients not taking prescription medicines: $258B (source: http://www.fiercehealthcare.com/story/patients-not-taking-medications-cost-300b/2011-05-27)

- Number of people who should be taking prescription medications in the US: 133M (source: http://www.fiercehealthcare.com/story/patients-not-taking-medications-cost-300b/2011-05-27)

- Prescription use compliance rate: 0.5 (source: http://www.fiercehealthcare.com/story/patients-not-taking-medications-cost-300b/2011-05-27)

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[114] The statistical significance between the means between the treatment group and comparison group in first survey period is 0.000 and in the second survey period 0.548. The statistical different between the means of the treatment group between the first survey and the second is 0.000 and between the comparison group means is 0.196.

[115] It assumed here that only 50% of household reporting being better able to afford prescriptions post-weatherization will actually be able to comply with their prescriptions(s) requirements.

Using the above equation and these inputs, the total first year benefit to society is $16M. Per unit the benefit is $193.98. The PV benefit to society over ten years is $155M. The PV per unit over a ten year period is $1,929.22. Table 4.46 summarizes these results.[116]

Table 4.46 Monetization of Benefits Attributable to Increased Use of Prescriptions

	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 10 years	PV Per Unit Benefit Over Ten Years
Households	0	0	0	0
Society	$15,587,079	$193.98	$155,016,925	$1,929.22
Total	$15,587,079	$193.98	$155,016,925	$1,929.22

Accuracy Assessment: It is logical to contend that weatherization could have a positive enough impact on household budgets that some households would better be able to afford prescriptions post-weatherization. It was observed through the national occupant survey that overall more households were able to afford prescriptions post-weatherization. It was not observed, though, to what extent households were better able to afford what could be many prescriptions in the case of elderly clients. It was also not observed to what extent increased affordability translated into enough compliance with prescriptions to result in reductions in overall medical costs. For these two reasons, this NEB is placed in Tier 2.

4.2.10 Reduced Need To Choose Between Heating Or Eating – Impacts on Low Birth Weight Babies

It is possible that the direct household income benefits attributable to WAP may allow some households to avoid a tradeoff between heating the home or affording the purchase of a healthy amount of food after weatherization. Studies have shown that pregnant women foregoing either food or heat subsequently have infants needing more medical care in their first year of life.[117] To explore this societal non-energy benefit, these questions were included in the national occupant survey:

Over the past 12 months, how often has your household not purchased food in order to pay an energy bill?

Over the past 12 months, how often has your household not paid energy bills in order to purchase food?

Pre-weatherization, 53% of households contained females of childbearing age (15-44) that traded off food for energy bills or energy bills for food, or both during the previous 12 months. This percentage dropped to 44% post-weatherization. The results for post-weatherization comparison group 1 and 2 are 31% and 21%, respectively.[118] Averaging the change between the treatment group pre-weatherization and the comparison group in the first survey period and the treatment group pre- and post-weatherization yields an estimated change of 15.5%. This non-energy benefit was quantified as follows:

[116] It should be noted that these results may be underestimated in that it is assumed that only one person per household would be better able to increase their use of prescriptions.
[117] Frank et al. 2006.
[118] The statistical significance between the means between the treatment group and comparison group in first survey period is 0.001 and in the second survey period 0.054. The statistical different between the means of the treatment group between the first survey and the second is 0.120 and between the comparison group means is 0.955.

- Benefit = (number of Wx Jobs completed in PY 2008) * (percent decrease in WAP households trading off heat for food, food for heat, or both) * (expected births per year per females aged 15-44) * (percent of births expected to be low birth weight) * (percent of LBW births avoided) * (avoided first year infant hospitalization costs)

The inputs used in this equation are as follows:

- Number of Wx Jobs completed in PY 2008: 80352 (source: S1 – State Program Information Survey)

- Percent decrease in WAP households trading off heat for food, food for heat, or both: 15.5% (source: S4 -- National Occupant Survey)

- Expected births per year per females aged 15-44: 64.1/1000 (source: http://www.cdc.gov/nchs/births.htm) Expected percent of births being low weight: 8.2% (source: http://www.cdc.gov/nchs/fastats/birthwt.htm)

- Percent low-birth weights avoided (Frank et al. 2006): 20%

- Hospitalization costs first year for low birth weight infants: $122,419 ($2013) (source: Rogowski, J. (1998) Cost-effectiveness of Care for Very Low Birth weight Infants. Pediatrics 012(1):35-43.)

Using the above equation and these inputs, the first year benefit to society $1.6M. Per unit the benefit is $19.92. The total PV to society over a ten year period is $16M. The PV per unit over a ten year period is $198.07. Table 4.47 summarizes these results.

Table 4.47. Monetization of Benefits Attributable to Reductions in Heat/Eat Tradeoffs

	First Year Program Benefit	First Year Per Unit Benefit	PV Program Benefit Over 10 years	PV Per Unit Benefit Over Ten Years
Households	0	0	0	0
Society	$1,600,298	$19.92	$15,915,321	$198.07
Total	$1,600,298	$19.92	$15,915,321	$198.07

Accuracy Assessment: It is logical to contend that weatherization could have a positive enough impact on household budgets that some households would be better able to afford both energy and food post-weatherization. Further, it is logical that pregnant women residing in these households would be relived of the burden of having to choose between eating and heating their homes. It was observed through the national occupant survey that overall more households were able to afford both food and heat post-weatherization. It was not observed, though, how many households in which pregnant women were residing were better able to afford food and heat post-weatherization. The reduction in the rate of LBWBs post-weatherization was generalized from the Frank et al. (2006) study, which pertained to LIHEAP subsidies. Also, this study’s results were generalized from the Boston area to the nation. Lastly, only a fairly out-of-date cost estimate re LBWB and first year medical costs could be found. For these reasons, this NEB is placed in Tier 3.

4.2.11 Reduced Need for Food Assistance

It is possible that the direct household income benefits attributable to WAP may allow some households to reduce their needs for food assistance payments.[119] To explore this societal non-energy benefit, this question was included in the national occupant survey:

Some households receive additional assistance to help pay for food. In the past 12 months did you or any members of your household receive food stamps or WIC assistance (Women, Infants, and Children utrition program)?

Fifty-six percent of the households surveyed pre-weatherization reported receiving food assistance, versus 50% post-weatherization, for the treatment group. The rate for the two comparison groups was also 50%.[120] Averaging the change between the treatment group pre-weatherization and the comparison group in the first survey period and the treatment group pre- and post-weatherization yields an estimated change of 6%. This non-energy benefit was quantified as follows:

- Benefit = (number of Wx Jobs completed in PY 2008) * (percent of reduction in households requiring food assistance) * (average annual per person food assistance subsidy) * (average WAP household size)

The inputs used in this equation are as follows:

- Number of Wx Jobs completed in PY 2008: 80352 (source: S1 – State Program Information Survey)

- Percent reduction in households requiring food assistance: 6% (source: S4 -- National Occupant Survey)

- Average monthly per person food assistance subsidy: $46.67 (Source: http://www.fns.usda.gov/pd/25wifyavgfd$.htm)

- Average WAP household size: 2.49 (Source: S4 -- National Occupant Survey)

Using the above equation and these inputs, the first year benefit to society is $560,000. Per unit the benefit is $6.97. The PV for the Program to society over ten years is $5.6M. The PV per unit over a ten year period is $69.34. Table 4.48 summarizes these benefits.

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

[120] The statistical significance between the means between the treatment group and comparison group in first survey period is 0.019 and in the second survey period 0.942. The statistical different between the means of the treatment group between the first survey and the second is 0.045 and between the comparison group means is .983.

Table 4.48. Monetized Benefits Attributable to Reduced Need for Food Assistance

	First Year Program Benefit	First Year per Unit Benefit	PV Program Benefit Over 10 years	PV Per Unit Benefit Over Ten Years
Households	0	0	0	0
Society	$6,723,000	$84.00	$66,862,000	$832.00
Total	$6,723,000	$84.00	$66,862,000	$832.00

Accuracy Assessment: It is logical to contend that weatherization could have a positive enough impact on household budgets that some households on food assistance would not feel the need to apply for continued assistance post-weatherization. It was observed through the national occupant survey that overall fewer households reported receiving food assistance post-weatherization. How much money was actually saved by each reporting household was not observed but a sound national study provided estimates for the value of this subsidy per household. Because the accuracy assessment did not identify any major uncertainties associated with this estimate, this NEB is placed in Tier 1.

4.2.12 Summary of Monetized Health-Related Benefits

Table 4.49 summarizes the monetization estimates developed above for the twelve categories of health and household-related non-energy benefits. The results are presented in two categories, households and society, by three tiers. Totals are presented in two manners, one column presents the total results another presents results without the value of lives saved, which is significant for several of the non-energy benefits. Overall, the highest benefits accrued to those categories where weatherization could prevent deaths (e.g.,, thermal stress and home fires) and hospitalizations (e.g.,, asthma, ability afford prescriptio

Table 4.49. Present Value of Per Unit and WAP Program Health-Related Benefits of Weatherization

Non-Energy Benefit (Present Value Per Unit)	Total	Total (Value of Life Excluded)	Tier 1 Societal	Tier 1 Household	Tier 2 Societal	Tier 2 Household	Tier 3 Societal	Tier 3 Household
Asthma	$2,009	-	$1,852	$157				
Thermal Stress-Cold	$3,911	$172	$3,892	$19				
Thermal Stress-Heat	$870	$85	$855	$15				
Food Assistance Reduction	$832	-	$832					
Reduction in Missed Days at Work	$201	-	$40	$161				
CO poisoning	$154	$7			$153	$1		
Improvement in Prescription Adherence	$1,929	-			$1,929	-		
Reduction in Use of Short-Term Loans	$71	-			-	$71		
Home Fires	$831	$175					$768	$63
Increased Productivity at Work Due to Improved Sleep	$1,813	-					$1,813	-
Increased Productivity at Home Due to Improved Sleep	$1,329	-					-	$1,329
Reduction in Low-Birth Weight Babies from Heat-or-Eat Dilemma	$198	-					$198	-
Total by Tiers (Present Value Per Unit)	$14,148	-	$7,471	$352	$2,082	$72	$2,779	$1,392
			$7,823		$2,154		$4,171	
Total by Tiers (Present Value WAP Program)	$1,136,883,221	-	$600,333,094	$28,295,957	$167,310,541	$5,766,863.04	$223,324,724.16	$111,878,910.72
			$628,629,051		$173,077,404		$335,176,766	

5. CONCLUSIONS AND FUTURE RESEARCH

Weatherization can be a major player in the new world of human health. It has been long known that weatherization provides direct benefits to households and indirect benefits to society and ratepayers. An expanded view, one which takes in new environmental health research, suggests that weatherization could also address human health issues associated with extreme weather events, outdoor air pollution, a broader range of indoor air pollutants, outdoor noise infiltrating indoors, and the mental health and well-being of occupants. The health-related non-energy benefits framework developed to guide this research suggests that weatherization could have a positive ripple effect on household budgets post-weatherization.

Survey results support contentions that weatherization improves the livability of homes and their physical characteristics. Numerous metrics indicate that occupants' health and well-being improved post-weatherization. Households are also better able to afford paying their energy bills, and afford food and prescriptions. The simultaneous equation model results provide insights into the complex relationships between weatherization and quality of life indicators such as bad mental health days, bad physical health days, and days without adequate rest and sleep.

The monetization exercise suggests that weatherization could lead to several thousand dollars of health-related benefits, spread between households and society. The benefits estimated in Section 4.2 are most certainly underestimated in that in many instances calculations were restricted to only one person per weatherized household and as suggested many potentially monetizable benefits were not included in the analyses.

Action Plan

It is essential that the health-related benefits of weatherization be better understood and quantified. Here are four broad areas of action for consideration.

- Supporting Human Health Research – In conjunction with the technical research mentioned below, human health needs to be tracked pre- and post-weatherization. This can be done with relatively simple and short surveys or can be quite elaborate and in-depth (e.g.,, requiring the donation of blood or urine samples for biomarkers and regular medical examinations). These data should be supplemented with data describing changes in medical costs, be they out-of-pocket to occupants (e.g.,, through the implementation of budget diaries) or charged to private or public health insurance programs. These data can be combined with data on weatherization measures installed and unit costs to improve our understanding of the most cost effective ways to achieve both energy savings and health-benefits. It is also important to include other factors that can influence human health beyond those potentially touched by weatherization to further enrich our understanding of the relationships between home, life, and health.

- Supporting Technical Research – The main argument that weatherization can reduce a wide variety of environmental risks to human health has a significant degree of verisimilitude. However, much additional research needs to be done to support the various arguments. For example, infiltration of outdoor air pollutants into homes pre- and post-weatherization needs to be measured for different levels and types of outdoor air pollutants, and different levels of air sealing and ventilation solutions for different housing types and climates. It would be particularly interesting to make measurements of indoor air contaminants just prior to and during major emission 'events', such as a forest fire. In addition, research needs to be done to evaluate the degree of noise pollution mitigation that weatherization measures can provide.

- Collaborating with the Medical Community – The weatherization community needs to closely collaborate with the medical community to design and implement such projects. Additionally, as the medical community learns more about the benefits of weatherization, perhaps physicians will 'prescribe' weatherization plus health solutions to their clients, to be implemented by local weatherization communities. This innovative idea is taking hold in other locales, such as Liverpool, England.[121] The medical research community might also be moved to include weatherization as an important explanatory variable in their research. Lastly, the medical community could include the weatherization community in their efforts to build a more effective early warning system to combat emerging public health epidemics.

- Extended Leveraging – This model takes the weatherization community way beyond the usual leveraging partners of energy assistance programs and utility companies to include the gamut of human health related organizations. These organizations include public and private health insurance programs, public and private sector organizational wellness programs, public health departments, and even federal, state and local level air pollution monitoring programs.

[121] IEA Ibid

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APPENDIX A. CHARACTERIZATION OF ASTHMA SAMPLES

APPENDIX A. CHARACTERIZATION OF ASTHMA SAMPLES

Table A.1. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Same Household Sample by Climate Zone

Climate Zone	Research Group	Very Cold	Cold	Moderate	Hot-humid	Hot-dry
Whole Survey Sample	Treatment	26.5%	47.8%	16.5%	7.1%	2.1%
	Comparison	26.0%	41.2%	22.0%	8.1%	2.6%
Whole Asthma Sample	Treatment	22.3%	53.2%	19.1%	4.3%	1.1%
	Comparison	25.2%	40.7%	26.0%	7.3%	0.8%
Asthma Sample-Same Household	Treatment	26.8%	58.5%	7.3%	7.3%	0.0%
	Comparison	30.8%	38.5%	21.2%	7.7%	1.9%

Table A.2. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Same Household Sample by Location

Location	Research Group	City	Town	Suburbs	Rural
Whole Survey Sample (n=1459)	Treatment	31.2%	26.4%	10.3%	32.1%
	Comparison	29.5%	26.1%	9.9%	34.6%
Whole Asthma Sample (n=214)	Treatment	28.0%	20.4%	11.8%	39.8%
	Comparison	28.9%	28.1%	9.1%	33.9%
Asthma Sample-Same Household (n=93)	Treatment	24.4%	24.4%	9.8%	41.5%
	Comparison	38.0%	26.0%	8.0%	28.0%

Table A.3. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Same Household Sample by Housing Type

Housing Type	Research Group	SF Detached	SF Attached	Small MF (2-4)units	Large MF (5+ Units)	Mobile Home
Whole Survey Sample (n=1467)	Treatment	70.1%	5.6%	2.0%	0.5%	22.0%
	Comparison	73.3%	5.7%	1.5%	0.6%	18.8%
Whole Asthma Sample (n=216)	Treatment	59.6%	8.5%	2.1%	1.1%	28.7%
	Comparison	73.8%	4.1%	0.8%	0.8%	20.5%
Asthma Sample-Same Household (n=93)	Treatment	61.0%	12.2%	4.9%	0.0%	22.0%
	Comparison	73.1%	7.7%	1.9%	0.9%	15.4%

Table A.4. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Same Household Sample by Main Heating Equipment

Main Heating System	Research Group	Heat Pump	Central Furnace	Steam /HW System	Built in Electric	Built in floor/ wall pipeless furnace	Built-in room heater; gas, oil or kerosene	Heating Stove; wood, coal or coke	Portable Heaters	Fire-place
Whole Survey Sample (n=1467)	**Treatment**	3.4%	72.3%	6.8%	4.3%	1.1%	4.5%	3.9%	2.5%	0.9%
	Comparison	3.9%	72.5%	8.4%	5.6%	1.1%	3.8%	2.0%	1.8%	0.8%
Whole Asthma Sample (n=216)	**Treatment**	4.3%	65.2%	8.7%	7.6%	0.0%	4.3%	5.4%	3.3%	1.1%
	Comparison	4.2%	75.8%	5.0%	4.2%	1.7%	3.3%	3.3%	1.7%	0.8%
Asthma Sample-Same Household (n=93)	**Treatment**	7.3%	58.5%	9.8%	7.3%	0.0%	4.9%	4.9%	4.9%	2.4%
	Comparison	0.0%	82.4%	5.9%	2.0%	3.9%	2.0%	3.9%	0.0%	0.0%

Table A.5. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Same Household Sample by Secondary Heating

Heating Characteristics	Research Group	Use other types of heating;	Built-in room heater; gas/oil or kerosene	Portable Heaters; NG	Portable Heater; kerosene	Heating Stove	Fireplace
Whole Survey Sample (n=1467)	Treatment	46.9%	0.3%	0.7%	2.3%	10.8%	11.5%
	Comparison	40.2%	3.5%	0.6%	3.5%	10.4%	14.2%
Whole Asthma Sample (n=216)	Treatment	41.9%	2.6%	0.0%	5.1%	7.7%	7.7%
	Comparison	41.3%	4.1%	2.0%	2.0%	12.2%	12.2%
Asthma Sample-Same Household (n=93)	Treatment	41.5%	0.0%	0.0%	5.9%	0.0%	11.8%
	Comparison	44.2%	0.0%	4.3%	0.0%	13.0%	13.0%

Table A.6. Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Same Household Sample by Cooking Fuel Type

Cooking Fuel	**Research Group**	Natural Gas Cook Stove
Whole Survey Sample (n=1467)	Treatment	35.5%
	Comparison	34.6%
Whole Asthma Sample (n=216)	Treatment	25.5%
	Comparison	26.0%
Asthma Sample- Same Household (n=93)	Treatment	36.6%
	Comparison	30.8%

Table A.7: Characterization of the WAP Whole Asthma Sample Compared to the WAP Asthma-Same Household Sample by Mechanical Ventilation Pre- and Post-Weatherization

% of Head of Households Reporting Home has working exhaust fans in either kitchen or main bathroom by Group and by Sample	**Mechanical Ventilation**	**Difference**
Whole Sample-Treatment Group (**Pre-Wx**; n=651)	65.1%	(+)12.7%
Whole Sample-Treatment Group(**Post-Wx** 1-year; n=392)	77.8%	
Whole Sample-Comparison Group (**Post-Wx** 1-Year; n=794)	75.1%	(-)0.6%
Whole Sample-Comparison Group(**Post-Wx** 2-years; n=424)	74.5%	
Whole Asthma Sample-Treatment Group (**Pre-Wx**; n=94)	73.4%	(+)10.2%
Whole Asthma Sample-Treatment Group (**Post-Wx** 1-year; n=55)	83.6%	
Whole Asthma Sample-Comparison Group (**Post-Wx** 1-year; n=122)	72.1%	(+)1.3%
Whole Asthma Sample-Comparison Group (**Post-Wx** 2-years; n=64)	73.4%	
Asthma Sample-Same Household-Treatment Group (**Pre-Wx**; n=41)	75.6%	(+)7.3%
Asthma Sample-Same Household-Treatment Group (**Post-Wx** 1-year; n=41)	82.9%	
Asthma Sample-Same Household-Comparison Group (**Post-Wx** 1-year; n=52)	71.2%	(+)1.9%
Asthma Sample-Same Household-Comparison Group (**Post-Wx** 2-years; n=52)	73.1%	

APPENDIX B. FRAMEWORK FOR ASSESSING THE ACCURACY OF THE ESTIMATES OF NON-ENERGY BENEFITS

APPENDIX B. FRAMEWORK FOR ASSESSING THE ACCURACY OF THE ESTIMATES OF NON-ENERGY BENEFITS

B.1 FRAMEWORK

A peer review panel convened to assess the quality of the research methods employed by the retrospective and ARRA period evaluations of WAP noted that the approaches to monetizing the set of non-energy benefits identified in Section 4.2 above had varying degrees of rigor.[122] In other words, some of the monetization estimates appeared to have less uncertainty than others. The panel suggested that the evaluation develop a framework for assessing the accuracy of the estimates so that the estimates could be grouped into two tiers based on qualitative assessments of their accuracy. This Appendix presents the framework developed to assess the accuracy of the estimates.

The framework has two main components. The first component identifies the parts of the monetization approaches over which one could assess accuracy. Though each approach to monetizing the dozen non-energy benefits tackled in Section 4.2 is different, they do have commonalities. The estimation of each non-energy benefit is conceptualized to have these three parts:

- Direct Outcome of Weatherization– Weatherization directly causes this outcome (e.g.,, installation of insulation can keep homes warmer in the winter and cooler in the summer)
- Monetizable Health and Household-related Outcome Attributable to the Direct Outcome (e.g.,, keeping homes warmer in the winter can reduce thermal stress from being too cold)
- Monetary Estimates of Costs Associated with the Monetizable Outcome – This component addresses the cost savings associated with the monetizable outcome (e.g.,, avoided doctor's office visits, avoided emergency department visits, avoided hospitalizations, and avoided deaths from being too cold can all be monetized)

The second component of the framework facilitates the description of the strengths and weaknesses of each part of each monetization methodology for each non-energy benefit. It is proposed that these strengths and weakness be conceptualized as to how much uncertainty there may be surrounding each of the three parts of the monetized benefit. Uncertainty is addressed qualitatively through a framework that has the concept broken into these three aspects:[123]

- Inherent Uncertainty – There are factors associated with an estimate that lead to inherent uncertainty. In other words, there are no ways of reducing the uncertainty in the estimate because of the inherent characteristics of target of the estimation process.
- Operational Uncertainty – Uncertainty surrounds the estimate because some research tasks that could have been done to produce an accurate estimate could have been better done better or were not done at all.
- Use Value Uncertainty – Uncertainty surrounds the estimate because the data collected and estimate generated are not as useful as could be (e.g.,, data used to produce the estimate are quite out-of-date).

The following three tables breakdown the three aspects of uncertainty into sub-components and provide guidance about how one could assess each non-energy benefit over each sub-component using a three-level Likert Scale. One should view the ideas presented in the tables as a distillation and synthesis of

[122] The panel met in-person in Washington, DC on May 15-16, 2014.

[123] This three-part uncertainty framework was first set out in: Tonn, B. 2000. "Environmental Decision Making in the Face of Uncertainty," Environmental Practice, Vol. 2, No. 2, 188-202.

relevant concepts found in various literatures, including: social science research design; philosophy of knowledge; uncertainty representation in artificial intelligence, knowledge-based systems; and decision theory.

Inherent uncertainty is posited to be qualitatively discernable using seven criteria (See Table B1). An estimate can be characterized as having a low level of inherent uncertainty if there is a strong, well-recognized logical link between cause and effect, the research task is fact establishment (versus forecasting, for example, which is plagued by inherent uncertainties), the system under study is orderly (i.e., not chaotic or non-linear) and there few to no confounding factors. Inherent uncertainty can arise if the phenomenon under study is not directly observable. For instance it is not possible to directly observe a prevented event, like a home fire, though evidence can be assembled to support the contention that the event was prevented. How the research was conducted can also influence one's perception of the accuracy of an estimate. For example, data collected using strong experimental designs with random control groups and many trials is deemed to be more accurate than data collected using non-experimental designs, though by how much has never been quantified.

Table B.1 Inherent Uncertainty

Level of Uncertainty	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Low	Yes, it is strong, well known and agreed upon	Fact establishment	Yes, it was directly observed	Linear/orderly	Strong experimental/ quasi experimental	Few to none
Medium	Most experts would agree the link is extremely plausible	Theory development	No, but it was inferred from other direct observations	Mostly linear/ somewhat volatile	Non-experimental, limited pre-post data	Several
High	No, the link is speculative at best	Forecasting	No, its existence was assumed from other studies	Non-linear/ chaotic; sensitive to initial conditions	Other non-experimental or only used secondary data	Many

Operational uncertainty is operationalized using four criteria (See Table B2). As might be expected, these criteria are much less philosophical/epistemological than those introduced above. They focus totally on how well the phenomenon under study was measured, how much data were collected, the quality of the data, and the quality of the estimation procedure.

Table B.2 Operational Uncertainty

Level of Uncertainty	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Low	Yes	Yes	Yes	Yes
Medium	No, inferred from other direct measurements and logic	Adequate	There are some minor data quality issues	It was satisfactory but a better one could have been used
High	Inferred from secondary sources	No, too small and/or unrepresentative	No, there are major data quality issues	No (e.g.,, billing histories were not weather normalized)

Table B.3 sets out the three criteria used to assess use value uncertainty. The essence of this third component of the framework is that even if the estimate has low inherent uncertainty and was well estimated, it could still prove useless in the particular monetization context. For example, the estimate could be decades out-of-date or the result was developed for a specific context (e.g.,, California) and to use it one needs to believe that the estimate can be generalized to the entire country. The estimate may also not fit in well into the policy making context.

Table B.3 Use Value Uncertainty

Level of Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Low	Very up-to-date	Not at all	Exactly what is needed
Medium	Less up-to-date but still relevant	Some but still relevant	A close proxy for what is needed
High	Quite out-of-date	A great deal	A distant proxy

Many potential issues identified in Tables B.1-B.3 do not afflict the monetization approaches documented in Section 4.2. For example, all of the non-energy benefits were chosen to be policy relevant. However, it has been documented in other contexts (e.g.,, environmental policy) that research results forthcoming from the scientific community do not always well support the public policy process. These potential issues are included in this framework for completeness, to provide the fullest context to judge the estimates, and so the framework could be used for the assessment of the accuracy of other non-energy benefits, such as the environmental emissions benefits discussed in a separate evaluation report.

B.2 HEALTH AND HOUSEHOLD-RELATED NON-ENERGY BENEFITS ACCURACY ASSESSMENTS

This part of the Appendix contains detailed uncertainty assessments for each of the twelve non-energy benefits discussed in Section 4.2. Below each assessment are comments that help explain the assessment.

B.2.1 Reduced Carbon Monoxide Poisonings

Direct Outcome: Reduction in Carbon Monoxide Poisoning Risk

Level of Inherent Uncertainty	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low/Medium	Low	Low	Low
Comments	A tenet of the program that Wx will take care of CO problems	Fact establishment	Inferred from installation of Wx measures	Linear, there is a straightforward relationship between installing CO monitors and reducing CO poisoning	Strong experimental design to collect data on the installation of CO monitors	Few to none.

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium	Low	Low	Low
Comments	Reduced poisoning and deaths from CO were not observed. Instead, these benefits were inferred from installation of CO monitors	Yes, a large and representative sample of weatherized homes was used.	Yes, straightforward to report whether a home received a CO monitor	Straightforward descriptive statistics.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Outcome: Reduced Physicians Visits, ED Visits, Hospitalizations, Deaths

Level of Inherent Uncertainty	**Is there a logical link between the direct outcome and this monetized outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Medium	Low	Low	Low
Comments	Yes, there is a well-known link between CO exposure and these monetized outcomes	Fact estimation	It is difficult to directly observe prevented deaths.	Linear.	Assuming that cited studies were done well	None.

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium	Low	Low	Low
Comments	No, secondary research provided estimates for these non-energy benefits attributable to the installation of CO monitors	Assuming the secondary studies are well done.	Assuming the secondary studies are well done.	Assuming the secondary studies are well done.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Recent data	No generalizations were needed	Very policy relevant

Monetized Estimate: Costs of Physicians Visits, ED Visits, Hospitalizations, Prevented Deaths

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium	Low	Low	Low
Comments	No, actual cost reductions attributable to the installation of CO monitors was not measured. The study used national medical cost databases.	Assuming the national costs studies are done well	Assuming the national cost studies are done well	Assuming the national cost studies are done well

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Most up-to-date medical cost data	Found the proper diagnostic codes	Very high.

B.2.2 Reduced Home Fires

Direct Outcome: Reduced Fire Risk in Home

<u>Level of Inherent Uncertainty</u>	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Medium	Medium	High	High
Comments	Strong case can be made that Wx reduces fire risks	Fact estimation	No, inferred from installation of measures.	Fire is complex, many factors involved.	Fire data were national and required subsetting and weighting to proxy the WAP population.	There are many situations that could lead to fires, impact damages, injuries, deaths

<u>Level of Operational Uncertainty</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium/High	Low	Medium/High	Medium
Comments	Wx measures installed and fire contributors are well known, but the link between measures and fire causes and suppression factors has not been directly researched and measured.	Databases have large number of homes with measures installed and homes that caught on fire.	Missing data to link Wx to the reduction in the probability of fire	The procedures to subset and weight data are well defined and follow the literature. Attributing prevention requires a few major assumptions, but careful steps were taken to err on the side of being conservative.

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Outcome: Reduced Damages, Injuries, Deaths from Fire

<u>Level of Inherent Uncertainty</u>	**Is there a logical link between the direct outcome and this monetized**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**

	outcome?					
Rating	Low	Low	Medium	Low	Low	Low
Comments	Yes, there is a well-known link between fires and these monetized outcomes	Fact estimation	Prevented deaths are unobservable. Did not observe injuries, damages. Used secondary sources.	Linear	Assuming secondary studies were well done.	None.

<u>Level of Operational Uncertainty</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium	Low	Low	Low
Comments	No, inferred from measures installed	Assuming the secondary studies are well done. Datasets are large and extensive. Fire data were adjusted to represent WAP population.	Assuming the secondary studies are well done.	Assuming the secondary studies are well done. Estimates followed methodology published by the National Fire Protection Association.

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Recent data	No generalizations were needed	Very policy relevant

Monetized Estimate:

<u>Level of Operational Uncertainty</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium	Low	Low/Medium	Low
Comments	No, actual cost reductions attributable to the installation of Wx measures was not measured. The study used national medical cost databases and secondary studies.	Assuming the secondary studies are well done.	Assuming the secondary studies are well done. NFIRS property loss estimates are approximate and contained missing entries.	Assuming the secondary studies are well done.

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low/Medium	Low	Low
Comments	Medical cost data from databases and	Found the proper diagnostic codes and used a very thorough study of home fire injuries.	Very high

	NFIRS property loss were up-to-date. Much injury cost data came from a 2009 study using multiyear averages from 1995-2003.		

B.2.3 Reduced Thermal Stress on Occupants

Direct Outcome: Home kept at safer temperatures

Level of Inherent Uncertainty	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low	Low	Low	Low
Comments	Weatherization directly impacts ability to keep home at a safe temperature.	Fact establishment	It has been observed directly by weatherization providers though in this case were observed through a national survey.	There is a linear relationship between unsafe temperatures inside the home and thermal stress on an occupant.	Strong experimental design for the national occupant survey.	None. Some occupants may be more vulnerable to the effects of extreme temperatures; however, this high risk population is the one that WAP serves.

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low	Low	Low	Low
Comments	No, but was ascertained through survey responses.	Yes, the national occupant survey was representative with a reasonable sample size.	Yes, closed-ended survey question.	Used difference of means between pre-post treatment and pre-treatment and post-control.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Outcome: Decreased occurrences of seeking health care due to heat and cold-related illnesses

<u>Level of Inherent Uncertainty</u>	**Is there a logical link between the direct outcome and this monetized outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low/Medium	Low	Low	Low
Comments	Yes, there is a well-known relationship between unsafe temperatures and illnesses or fatalities caused by these extreme temperatures.	Fact estimation.	Incidences of seeking medical care for exposure to extreme temperatures were reported through the occupant survey; however, the survey did not ask if a fatality within the household occurred due to extreme temperature exposure. In addition, it is possible that if the head of household died then a follow up survey could not be conducted.	Linear relationship between reduced occurrences of medical treatment and home able to be kept at safer temperatures.	Strong experimental with respect to the national occupant survey. In addition, national medical datasets were utilized.	None.

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low/Medium	Low	Low	Low
Comments	Yes, the decrease in occurrences of seeking medical care for heat or cold-related illnesses was reported on national occupant survey (pre and post). However, since the occupant survey did not differentiate which *type* of medical attention was required (i.e. hospitalization, emergency dept. or physician office); data for the general US population was utilized to establish the proportion of types of treatment sought for heat and cold-related illnesses. This same proportion was applied to the WAP population.	Yes. Sample size is representative for the population WAP serves.	Yes, closed-ended survey questions on national occupant survey.	Yes. We feel confident that utilizing pre-weatherization and post-weatherization survey data to calculate a decrease in occurrences of seeking health care is more than reasonable.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Estimate: Value of decreased occurrences of seeking health care from heat and cold-related illnesses

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low/Medium	Low	Low	Low
Comments	Did not collect actual cost data from households but cited average costs incurred for medical treatment as reported in national medical data bases.	Yes. National data bases.	Medical data bases provide costs incurred for all types of medical treatment utilized in the monetization of this NEB.	Yes, the method used to assume the same proportion of individuals seeking health care within the general population would be the same for the WAP population is a quite reasonable, if not conservative, assumption.

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Data from equivalent years as the data from the occupant surveys.	No generalizations were needed.	Very relevant.

B.2.4 Reduced Asthma-related ED Visits, Hospitalizations, Other Direct Medical Costs, and Indirect Costs

Direct Outcome:

Level of Inherent Uncertainty	Is there a logical link between Wx and this outcome?	What is the fundamental research task?	Is the phenomenon underlying the NEB directly observable?	In what type of system does the underlying phenomenon exist?	What was the research design implemented to collect data about this phenomenon?	How many confounding factors could the phenomenon be attributed to?
Rating	Low	Low	Low	Low	Low	Medium
Comments	Weatherization directly impacts exposure to evidence based environmental and psycho-social asthma triggers	Fact establishment	Changes in asthma symptoms and utilization of healthcare for treatment of asthma were directly observed through a national survey. Data collected was from and for head of households only.	There is a linear relationship between environmental asthma triggers and asthma morbidity	Strong experimental design for the national occupant survey.	Asthma is a complex health issue with multiple triggers and levels of severity disproportionately impacting different populations.

<u>Level of Operational Uncertainty</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low/Medium	Low	Low	Low/Medium
Comments	No, but was ascertained through self-reported survey responses. Changes in asthma symptoms and use of urgent care services were not directly measured for children. The same changes observed in the adult population were applied to the child population. This underestimates the potential impact as children generally have higher incidence of using urgent care facilities due to asthma than adults.	Yes, the national occupant survey was representative with a reasonable sample size.	Yes, closed-ended survey question collected through a computer assisted telephone interview.	Used difference of percentages between pre- and post-weatherization within the treatment group sample for those reporting still having asthma. No control or comparison group was used due to diverging sample characteristics. A logistic regression analysis was employed to provide further evidence that weatherization (with an inverse relationship) is a predicting factor for urgent healthcare utilization to treat severe episodes of asthma.

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Survey data used was up to date	No generalizations were needed	Very relevant as no research known attempts to measure the direct asthma related health impacts of weatherization delivered through WAP without the inclusion of community health workers, education, or additional asthma trigger reduction measures. Measuring this impact also provides information necessary for inter-governmental agreements regarding collaborative healthy housing initiatives.

Monetized Outcome:

Level of Inherent Uncertainty	**Is there a logical link between the direct outcome and this monetized outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low	Low	Low	Low/Medium
Comments	Yes, ongoing research studies provide overwhelming evidence that addressing indoor environmental quality contributes to asthma trigger reduction and thereby asthma symptoms and treatment needs	Fact Estimation	Changes in asthma symptoms and utilization of healthcare for treatment of asthma were directly observed through a national survey. Changes in asthma symptoms and use of urgent care services were not directly measured for children. The same changes observed in the adult population were applied to the child population. This underestimates the potential impact as children generally have higher incidence of using urgent care facilities due to asthma than adults	There is a linear relationship between environmental asthma triggers and asthma morbidity and direct ICD-9 codes for asthma and respiratory health with accompanying national estimates of costs	Strong experimental with respect to the national occupant survey. In addition, national medical datasets were utilized.	The experimental design of the survey addresses confounding variables. However, only survey responses within the treatment group were used for this analysis due to the diverging characteristics between the treatment and comparison groups. Confounding variables would include asthma triggers other than home-based environmental triggers such as outdoor air quality, time spent outdoors, and exercise activity.

<u>**Level of Operational Uncertainty**</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low/Medium	Low	Low	Low/Medium
Comments	Yes, the decrease in occurrences of seeking medical care for asthma related symptoms was reported in national occupant survey (pre and post). Time since last symptoms was also collected; data for the general US population was utilized to establish the proportion of children with different demographics, their asthma rates, and use of urgent care treatment. This same proportion was applied to the WAP child population.	Yes, the national occupant survey was representative with a reasonable sample size.	Yes, closed-ended survey question collected through a computer assisted telephone interview.	Used difference of percentages between pre- and post-weatherization within the treatment group sample for those reporting still having asthma. No control or comparison group was used due to diverging sample characteristics. A logistic regression analysis was employed to provide further evidence that weatherization (with an inverse relationship) is a predicting factor for urgent healthcare utilization to treat severe episodes of asthma within the treatment group population.

<u>**Level of Use Value Uncertainty**</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low/Medium	Low	Low
Comments	Medical data used estimate the costs for urgent care (ED and Hospitalization were up to date. However, other direct medical expenses and indirect costs associated with asthma that matched the data collected in the survey were outdated (1997). Medical inflation was used to estimate the costs of this part of the asthma health related benefit	No generalizations were needed	Very relevant as no research known attempts to measure the direct asthma related health cost impacts of weatherization delivered through WAP without the inclusion of community health workers, education, or additional asthma trigger reduction measures. Measuring this impact also provides information necessary for inter-governmental agreements regarding collaborative healthy housing initiatives.

Monetized Estimate:

<u>Level of Operational Uncertainty</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low/Medium	Low	Low	Low
Comments	Did not collect actual cost data from households but cited average costs incurred for medical treatment as reported in national medical data bases. And used national report to determine the other medical costs and indirect costs for the entire asthma population in the US	Yes, A national database was used for estimating the direct medical costs. The report used to monetize direct medical costs other than ED and Hospitalization and indirect costs was a national sample with an adequate sample size	Medical databases provide costs incurred for all types of medical treatment utilized in the monetization of this NEB.	Yes, the method used to assume the same proportion of individuals seeking asthma related health care within the general low-income US asthma population would be the same for the WAP population is reasonable. Using the proportion of direct medical costs and indirect costs for the whole US asthma population is also reasonable, if not conservative.

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low/Medium	Low	Low
Comments	Data was used from equivalent years as the data from the occupant surveys for the monetization of the ED and Hospitalization reductions. However, other direct medical expenses and indirect costs associated with asthma that matched the data collected in the survey were outdated (1997). Medical inflation was used to estimate the costs of this part of the asthma health related benefit	No generalizations were needed	Very relevant as no research known attempts to measure the direct asthma related health cost impacts of WAP. Measuring this impact also provides information necessary for inter-governmental agreements regarding collaborative healthy housing initiatives. More specifically, monetizing this benefit contributes to the discussion on reimbursable Medicaid/health insurance costs for home-related audits and interventions.

B.2.5 Improved Worker Productivity Due to Improvements in Sleep

Direct Outcome: Better Sleep/Rest

Level of Inherent Uncertainty	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low	Low	Low	Medium
Comments	A strong case can be made that weatherization can improve sleep/rest by making the temperature in homes more comfortable, reducing the intrusion of outdoor noise, reducing budget stress.	Fact estimation.	It can be observed directly though in this case was observed through a national survey.	The system aspects of sleep and rest are fairly straightforward to describe.	Strong experimental design for the national occupant survey.	Many factors can complicate observations about sleep and rest.

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low	Low	Low	Low
Comments	No, but was ascertained through survey responses.	Yes, the national occupant survey was representative with a reasonable sample size.	Yes, closed-ended survey question.	Used difference of means between pre-post treatment and pre-treatment and post-control

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Outcome: Improved Productivity at Work

Level of Inherent Uncertainty	**Is there a logical link between the direct outcome and this monetized outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low	Medium	Medium	High
Comments	Yes, there is a well-known relationship between sleep/rest and worker productivity.	Fact estimation.	Productivity at work can be measured.	Productivity exists within a complex organizational system.	The study cited for this research used adequate research methods.	There are numerous factors in addition to sleep and rest that could impact worker productivity.

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low	Medium	Low	Low
Comments	The cited study directly observed changes in productivity.	The scope of the study was limited in the number of unit contexts studied.	The data collected are high in quality.	Yes, the method used to estimate improvements in productivity was reasonable.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	High	Low
Comments	The cited study is fairly recent.	Really limited number of unit types, probably not completely representative of jobs held by WAP recipient demographic.	Very relevant.

Monetized Estimate: Value of Improved Productivity at Work

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low	Medium	Low	Low
Comments	The study directly observed changes in productivity and measured the economic value of those changes.	The scope of the study was limited in the number of unit contexts studied.	The data collected are high in quality.	Yes, the method used to estimate improvements in productivity was reasonable.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	High	Low
Comments	The cited study is fairly recent.	Really limited number of unit types, probably not completely representative of jobs held by WAP recipient demographic.	Very relevant.

B.2.6 Improved Household Work Productivity Due to Improvements in Sleep

Direct Outcome: Better Sleep/Rest

Level of Inherent Uncertainty	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low	Low	Low	Medium
Comments	A strong case can be made that weatherization can improve sleep/rest by making the temperature in homes more comfortable, reducing the intrusion of outdoor noise, reducing budget stress.	Fact estimation.	It can be observed directly though in this case was observed through a national survey.	The system aspects of sleep and rest are fairly straightforward to describe.	Strong experimental design for the national occupant survey.	Many factors can complicate observations about sleep and rest.

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low	Low	Low	Low
Comments	No, but was ascertained through survey responses.	Yes, the national occupant survey was representative with a reasonable sample size.	Yes, closed-ended survey question.	Used difference of means between pre-post treatment and pre-treatment and post-control

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Outcome: Improved Work Productivity at Home

<u>Level of Inherent Uncertainty</u>	Is there a logical link between the direct outcome and this monetized outcome?	What is the fundamental research task?	Is the phenomenon underlying the NEB directly observable?	In what type of system does the underlying phenomenon exist?	What was the research design implemented to collect data about this phenomenon?	How many confounding factors could the phenomenon be attributed to?
Rating	Medium	Low	Low	Low	Medium	Medium
Comments	Yes, there is a well-known relationship between sleep/rest and worker productivity, but this relationship is being extended to home-based work.	Fact estimation.	Productivity in jobs that resemble work done in the home can be measured.	Home-based work productivity exists within a fairly straightforward household system.	The study cited for this research used adequate research methods.	There are other factors in addition to sleep and rest that could impact home-based work productivity.

<u>Level of Operational Uncertainty</u>	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Medium	Medium	Low	High
Comments	The cited study did not directly observe changes in home-based work productivity.	The scope of the study was limited in the number of unit contexts studied.	The data collected are high in quality.	Yes, the method used in the study to estimate improvements in productivity was reasonable. Still, assumptions were needed to estimate changes in home-based productivity.

<u>Level of Use Value Uncertainty</u>	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	High	Low
Comments	The cited study is fairly recent.	The cited study did not directly address those types of jobs normally performed in homes. Estimates of productivity improvements were generalized to the home-based work sector.	Very relevant.

Monetized Estimate: Value of Improved Productivity at Work

Level of Operational Uncertainty	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Medium	Medium	Low	High
Comments	The cited study did not directly observe changes in home-based work productivity nor directly measure the economic value of any changes in home-based productivity.	The scope of the study was limited in the number of unit contexts studied.	The data collected are high in quality.	Yes, the method used in the study to estimate improvements in productivity was reasonable. Still, assumptions were needed to estimate the value of changes in home-based productivity.

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	High	Low
Comments	The cited study is fairly recent.	The cited study did not directly address those types of jobs normally performed in homes. Estimates of the economic value of productivity improvements were generalized to the home-based work sector.	Very relevant.

B.2.7 Fewer Missed Days at Work

Direct Outcome: Weatherization Improves Health of Occupants

Level of Inherent Uncertainty	Is there a logical link between Wx and this outcome?	What is the fundamental research task?	Is the phenomenon underlying the NEB directly observable?	In what type of system does the underlying phenomenon exist?	What was the research design implemented to collect data about this phenomenon?	How many confounding factors could the phenomenon be attributed to?
Rating	Low	Low	Low	Medium	Low	Medium
Comments	There is a growing body of research and consensus in the research community that weatherization can improve the health of occupants	Fact establishment	Improvements in health can be observed directly, in this case through an extensive survey	Human health is a complex system	Strong experimental design used for the national occupant survey	Many factors contribute to human health and changes in human health

Level of Operational Uncertainty	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Low	Low	Low	Low
Comments	Numerous answers to numerous questions in the national occupant study suggest occupants are healthier post-weatherization	Yes, nationally representative sample. Good sample sizes	Answers to closed-ended questions	Straightforward descriptive statistics were used

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Very up-to-date	Not at all	Very relevant

Monetized Outcome: Reduced Missed Days at Work

Level of Inherent Uncertainty	Is there a logical link between the direct outcome and this monetized outcome?	What is the fundamental research task?	Is the phenomenon underlying the NEB directly observable?	In what type of system does the underlying phenomenon exist?	What was the research design implemented to collect data about this phenomenon?	How many confounding factors could the phenomenon be attributed to?
Rating	Low	Low	Low	Low	Low	Low
Comments	There is a direct logical link between improvements in the health of occupants and reductions in missed days of work by the respondent	Fact estimation	Yes, in this case through a national survey	Going or not going to work is a straightforward context to study	Strong experimental design for the national occupant survey	There are relatively few factors that could prevent people from going to work, with health issues of workers and other household members one of the most important

Level of Operational Uncertainty	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Low	Low	Low	Low
Comments	Yes, employed respondents were directly surveyed about missed days at work	Yes, nationally representative sample. Good sample sizes	Answers to closed-ended questions	Used difference of means between pre-post treatment and pre-treatment and post-control

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Very up-to-date	Not at all	Very relevant

Monetized Estimate: Value of Reducing Missed Days at Work

Level of Operational Uncertainty	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Low	Low	Low	Low
Comments	No, but resources were found to estimate the average hourly wage of a low-income worker. Also found a study that indicated the percentage of low-income workers who get sick leave.	Studies were reasonable.	Studies were reasonable.	Using the studies to estimate wage benefits was straightforward.

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Very up-to-date	Not at all	Very relevant

B.2.8 Reduced Need for High Interest, Short-term Loans

Direct Outcome: Increase in Household Disposable Income

Level of Inherent Uncertainty	Is there a logical link between Wx and this outcome?	What is the fundamental research task?	Is the phenomenon underlying the NEB directly observable?	In what type of system does the underlying phenomenon exist?	What was the research design implemented to collect data about this phenomenon?	How many confounding factors could the phenomenon be attributed to?
Rating	Low	Low	Medium	Medium	Low	Low
Comments	Widely recognized that Wx saves households money	Fact estimation	Inferred from billing data; average HHD spends less on energy post-wx	Household energy use can be volatile (e.g.,, due to changes in HHD composition)	Strong experimental design to collect billing histories	Overall, installation of measures directly results in energy and energy cost savings

<u>Level of Operational Uncertainty</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low/medium	Low	Low	Low
Comments	No but energy bills were collected, then energy cost reductions were estimated	Nationally representative sample homes, good sample size	Billing histories were cleaned. EIA data energy data are accurate on energy costs	Yes, billing histories were weather normalized. Energy savings were estimated using industry standard PRISM-like software

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Outcome: Reduced Use of High-Interest, Short-term Loans

<u>Level of Inherent Uncertainty</u>	**Is there a logical link between the direct outcome and this monetized outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low	Medium	Low	Medium
Comments	There is a logical link to a household having more discretionary income and having less need to rely on these types of loans to make ends meet.	Fact establishment	Yes, use of loans and reduction in use are observable.	Household budgets can be volatile	Strong experimental with respect to the national occupant survey	Could be several other factors that impact household budget that could impact the ability to reduce use of these loans

<u>Level of Operational Uncertainty</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low	Low	Low	Low
Comments	Yes, albeit subjectively from a survey of clients	Yes, nationally representative sample. Good sample sizes	Answers to closed-ended questions	Used difference of means between pre-post treatment and pre-treatment and post-control

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low

Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Estimate: Reduced Cost to Household in Interest Charges

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium/High	Medium	Medium	Medium
Comments	No, this was not measured. Several secondary sources were used to estimate average interest charges for each loan type.	The studies appear have a range of their own strengths and weaknesses.	The data used in the studies have their own strengths and weaknesses.	Several important assumptions were made about the size and frequency of loans used by the responding households.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Medium	Low	Low
Comments	Some studies were more up-to-date than others.	No generalizations were needed	Very relevant

B.2.9 Increased Ability to Afford Prescriptions

Direct Outcome: Increase in Household Disposable Income

Level of Inherent Uncertainty	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Medium	Medium	Low	Low
Comments	Widely recognized that Wx saves households money	Fact estimation	Inferred from billing data; average HHD spends less on energy post-wx	Household energy use can be volatile (e.g.,, due to changes in HHD composition)	Strong experimental design to collect billing histories	Overall, installation of measures directly results in energy and energy cost savings

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Low/medium	Low	Low	Low
Comments	No but energy bills were collected, then energy cost reductions were estimated	Nationally representative sample homes, good sample size	Billing histories were cleaned. EIA data energy data are accurate on energy costs	Yes, billing histories were weather normalized. Energy savings were estimated using industry standard PRISM-like software

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Outcome: Ability Afford Prescriptions

Level of Inherent Uncertainty	Is there a logical link between the direct outcome and this monetized outcome?	What is the fundamental research task?	Is the phenomenon underlying the NEB directly observable?	In what type of system does the underlying phenomenon exist?	What was the research design implemented to collect data about this phenomenon?	How many confounding factors could the phenomenon be attributed to?
Rating	Low	Low	Low	Medium	Low	Medium
Comments	Yes, it is reasonable to assume that households with more discretionary income would be better able to afford prescriptions	Fact estimation	Survey respondents indicated whether they were able to afford prescriptions pre- and post-wx	Household budgets can be volatile	Strong experimental with respect to the national occupant survey	Could be several other factors that impact household budget that could impact the ability to afford prescriptions

Level of Operational Uncertainty	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Low	Low	Low	Low
Comments	Yes, albeit subjectively from a survey of clients	Yes, nationally representative sample. Good sample sizes	Answers to closed-ended questions	Used difference of means between pre-post treatment and pre-treatment and post-control

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Same as above	Same as above	Same as above

Monetized Estimate: Reduced Health Care Costs

<u>Level of Operational Uncertainty</u>	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium	Low	Low	Medium/High
Comments	Households' ability afford prescriptions was not directly observed. It is unknown how many prescriptions per person became affordable. Estimates of national costs of not taking prescriptions as directed were taken from one national study.	Yes, data included in the national study were representative.	Yes.	It is not known how the ability to afford prescriptions translated into fully complying with medical directions re the prescriptions. It was assumed that only 50% of the households that reported better being able to afford prescriptions actually ended up following all their prescriptions as directed.

<u>Level of Use Value Uncertainty</u>	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent	No generalizations were needed	Very

B.2.10 Reduced Need to Choose Between Heating or Eating – Impacts on Low Birth Weight Babies

Direct Outcome: Reduction in choosing between heating and eating

<u>Level of Inherent Uncertainty</u>	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Low	Low	Low	Medium
Comments	Yes, one can make a strong case that weatherization can result in enough energy savings to allow households to spend more money on both food and heat at critical times.	Fact estimation	The national survey asked questions related to households trading off buying food for energy and vice versa.	Respondents clearly make decisions about food versus energy	National survey with strong experimental design with control group	Other things could impact household budget that could impact this decision

<u>Level of Operational Uncertainty</u>	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Low/medium	Low	Low	Low
Comments	Have survey responses but no direct observations in real time re the decision problem. Did not collect information on the number of pregnant women in each weatherized household. Used secondary data sources to estimate the number.	Large, nationally representative sample	Answers to closed ended questions	Used difference of means between pre-post treatment and pre-treatment and post-control

<u>Level of Use Value Uncertainty</u>	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Very recent	No generalization	Pretty straightforward

Monetized Outcome: Low-birth weight babies

<u>Level of Inherent Uncertainty</u>	Is there a logical link between the direct outcome and this monetized outcome?	What is the fundamental research task?	Is the phenomenon underlying the NEB directly observable?	In what type of system does the underlying phenomenon exist?	What was the research design implemented to collect data about this phenomenon?	How many confounding factors could the phenomenon be attributed to?
Rating	Low/Medium	Low	Medium/High	Medium	High	High
Comments	Famous study by Frank et al. makes the link between getting energy assistance and preventing LBWB	Fact estimation	Prevention of low-birth weight births is not observable. Did not collect data on LBWB pre or post-wx from households.	In general, one can assume that the reproduction process is complex.	Used secondary sources to estimate reduction in LBWB.	Many factors could lead to LBWB, especially in this population demographic.

<u>Level of Operational Uncertainty</u>	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	High	Low	Low	Low
Comments	Used the seminal Frank et al. study.	Good study	The Frank et al. study data quality were high.	Estimation procedures used were reasonable.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Medium	High	Low
Comments	Frank et al. is not a very recent study	Frank et al. study was done in Boston. Therefore, lacks diversity in climate zones, housing types. Had to generalize the outcomes. Also, the study was related to LIHEAP subsidies and therefore was generalized to weatherization.	This is a straightforward NEB.

Monetized Estimate: Medical costs of low-birth weight babies

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium/High	Medium	Medium	Low
Comments	Used one secondary study found in the literature on increased medical costs in first year for LBWB.	The study's sample size was adequate.	The study's data were adequate in quality.	The estimation procedure was reasonable.

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	High	Low	Low
Comments	Pretty out of date	The results did not have to be generalized.	Very relevant.

B.2.11 Reduced Need for Food Assistance

Direct Outcome: Increase in Household Disposable Income

Level of Inherent Uncertainty	**Is there a logical link between Wx and this outcome?**	**What is the fundamental research task?**	**Is the phenomenon underlying the NEB directly observable?**	**In what type of system does the underlying phenomenon exist?**	**What was the research design implemented to collect data about this phenomenon?**	**How many confounding factors could the phenomenon be attributed to?**
Rating	Low	Low	Medium	Medium	Low	Low
Comments	Widely recognized that Wx saves households money	Fact estimation	Inferred from billing data; average HHD spends less on energy post-wx	Household energy use can be volatile (e.g.,, due to changes in HHD composition)	Strong experimental design to collect billing histories	Overall, installation of measures directly results in energy and energy cost savings

Level of Operational Uncertainty	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Low/medium	Low	Low	Low
Comments	No but energy bills were collected, then energy cost reductions were estimated	Nationally representative sample homes, good sample size	Billing histories were cleaned. EIA data energy data are accurate on energy costs	Yes, billing histories were weather normalized. Energy savings were estimated using industry standard PRISM-like software

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Very recent data	No generalizations were needed	Very relevant

Monetized Outcome: Reduction in Food Assistance

Level of Inherent Uncertainty	Is there a logical link between the direct outcome and this monetized outcome?	What is the fundamental research task?	Is the phenomenon underlying the NEB directly observable?	In what type of system does the underlying phenomenon exist?	What was the research design implemented to collect data about this phenomenon?	How many confounding factors could the phenomenon be attributed to?
Rating	Low	Low	Low	Medium	Low	Medium
Comments	Yes, it is reasonable to assume that households with more discretionary income would not apply for food assistance	Fact estimation	Survey respondents indicated whether they received food assistance pre- and post-wx	Household budgets can be volatile	Strong experimental with respect to the national occupant survey	Could be several other factors that impact household budget that could impact need for food subsidies

Level of Operational Uncertainty	Was the phenomenon directly measured?	Was the sample size representative?	Are the data of high quality?	Was the estimation procedure used reasonable?
Rating	Low	Low	Low	Low
Comments	Yes, albeit subjectively from a survey of clients	Yes, nationally representative sample. Good sample sizes	Answers to closed-ended questions	Used difference of means between pre-post treatment and pre-treatment and post-control

Level of Use Value Uncertainty	How up-to-date are the data?	How much were the results generalized for this policy context?	How relevant is this variable to this policy context?
Rating	Low	Low	Low
Comments	Same as above	Same as above	Same as above

Monetized Estimate: Food Assistance per Household

Level of Operational Uncertainty	**Was the phenomenon directly measured?**	**Was the sample size representative?**	**Are the data of high quality?**	**Was the estimation procedure used reasonable?**
Rating	Medium	Low	Low	Low
Comments	Did not collect actual cost data from households but cited government study of actual food assistance usage by households	Yes, a dataset used in the study was of reasonable size	Yes, actual government payment data were used	Yes, appropriate statistical procedures were used to estimate average household food subsidy benefits

Level of Use Value Uncertainty	**How up-to-date are the data?**	**How much were the results generalized for this policy context?**	**How relevant is this variable to this policy context?**
Rating	Low	Low	Low
Comments	Very recent	No generalizations were needed	Very

APPENDIX C. ADDITIONAL INFORMATION RELATED TO REDUCED HOME FIRES

APPENDIX. C ADDITIONAL INFORMATION RELATED TO REDUCED HOME FIRES

Category (Dummy Variable Abbreviation) – NFIRS variable used for this category (either Equipment involved in ignition or Suppression factors)	
NFIRS	**DF2**
Equipment involved in ignition or suppression factors that could be addressed by the corresponding DF2 WAP measures, preventing fire ignition and spread.	WAP measure(s) installed that corresponds to the category.

Electrical Repair (EI1) – Equipment involved in ignition		
NFIRS		**DF2**
'200'	'Electrical distribution, power transfer, other'	Electrical repair df2_q62n_03
'210'	'Electrical wiring, other'	
'214'	'Wiring from meter box to circuit breaker'	
'215'	'Panelboard, switchboard, circuit breaker board'	
'216'	'Electrical branch circuit'	
'217'	'Outlet, receptacle'	
'218'	'Wall switch'	
'219'	'Ground fault interrupter, GFI'	
'222'	'Overcurrent, disconnect equipment'	
'226'	'Uninterrupted power supply (UPS)'	
'227'	'Surge protector'	
'260'	'Cord, plug, other'	
'261'	'Power cord, plug - detachable from appliance'	
'262'	'Power cord, plug - permanently attached'	
'263'	'Extension cord'	

Heating (EI2) – Equipment involved in ignition		
NFIRS		**DF2**
'100'	'Heating, ventilating & air conditioning, other'	New heating system (justified because cost effective) df2_q55a_03
'112'	'Heat pump'	New heating system (justified for reason other than cost effectiveness) df2_q55b_03
'121'	'Fireplace, masonry'	Space-heating system repair (e.g.,, controls, safety items, flues) df2_q55c_03 (repair)
'122'	'Fireplace, factory built'	df2_q55d_03 (tune-up)
'123'	'Fireplace, insert/stove'	Intermittent ignition device installed df2_q55f_03
'124'	'Stove, heating'	Other heating system mod 1 df2_q55g_03
'131'	'Furnace, local heating unit, built-in'	Mod 2 df2_q55h_03
'132'	'Furnace, central heating unit'	
'133'	'Boiler (power, process, heating)'	

'141'	'Heater, excluding catalytic and oil-filled heaters'	
'142'	'Heater, catalytic'	
'143'	'Heater, oil filled'	
'152'	'Steamline, heat pipe, hot air duct'	

Cooling (EI3) – Equipment involved in ignition		
NFIRS		**DF2**
'111'	'Air conditioner'	New AC (justified because cost effective) df2_q56a_03
		New AC system (justified for reason other than cost effectiveness) df2_q56b_03
		AC repair (e.g.,, controls, safety items, flues) df2_q56c_03 (repair)
		df2_q56d_03 (tune-up)
		Other AC mod 1 df2_q56f_03
		Mod 2 df2_q56g_03

Clothes Dryer (EI4) – Equipment involved in ignition		
NFIRS		**DF2**
'811'	'Clothes dryer'	Clothes dryer vent repair or replacement df2_q62z_03bc
'813'	'Washer/dryer combination (within one frame)'	

Refrigerator (EI5) – Equipment involved in ignition		
NFIRS		**DF2**
'652'	'Freezer when separate from refrigerator'	Refrigerator (justified because cost effective) df2_q60d_03
'656'	'Refrigerator, refrigerator/freezer'	Refrigerator (justified for reason other than cost effectiveness) df2_q60e_03

Water Heater (EI6) – Equipment involved in ignition		
NFIRS		**DF2**
'151'	'Water heater'	New water heater (justified because cost effective) df2_q59a_03
		New water heater (justified for reason other than cost effectiveness) df2_q59b_03
		Water-heating system repair df2_q59c_03
		Water-heater tank insulation wrap df2_q59d_03
		Pipe insulation df2_q59e_03
		Other water heating system measure df2_q59i_03
		Other water heating system measure df2_q59j_03

Chimney (EI7) – Equipment involved in ignition		
NFIRS		**DF2**
'120'	'Fireplace, chimney, other'	Install/repair metal chimney liner df2_q62t_03
'125'	'Chimney connector, vent connector'	
'126'	'Chimney - brick, stone, masonry'	
'127'	'Chimney - metal, including stovepipe, flue'	

Fans (EI8) – Equipment involved in ignition		
NFIRS		**DF2**
'113'	'Fan'	New bathroom exhaust fan installed df2_q57a_03
'654'	'Grease hood/duct exhaust fan'	New kitchen exhaust fan installed df2_q57b_03
		Ceiling/Whole House Fan df2_q56e_03

Lighting (EI9) – Equipment involved in ignition		
NFIRS		**DF2**
'230'	'Lamp, lighting, other'	Indoor lighting (energy efficient bulb or fixture) df2_q60a_03
'231'	'Lamp - tabletop, floor, desk'	Outdoor lighting (energy efficient bulb or fixture) df2_q60b_03
'233'	'Incandescent lighting fixture'	Lighting (indoor/outdoor location not recorded) df2_q60c_03
'234'	'Fluorescent lighting fixture, ballast'	
'235'	'Halogen lighting fixture or lamp'	
'236'	'Sodium, mercury vapor lighting fixtures or lamps;'	
'237'	'Work light, trouble light'	
'238'	'Light bulb'	

Smoke Alarm (SF1) – Suppression Factors		
NFIRS		**DF2**
'411'	'Delayed detection of fire'	Smoke alarm df2_q62a_03
'413'	'Alarm system malfunction'	

Windows/Doors (SF2) – Suppression Factors		
NFIRS		**DF2**
'151'	'Lack of fire barrier walls or doors'	New window (justified because cost effective)
'188'	'Quick release failure of bars on windows or doors'	New window (justified for reason other than cost effectiveness)
'448'	'Locked or jammed doors'	Window glazings
'613'	'Window type impedes egress'	Other window repair (e.g.,, sashes, frames)
		Storm window
		df2_q53a_03,df2_q53b_03,df2_q53c_03,df2_q53g_03,df2_q53h_03
		New door (justified because cost effective)
		New door (justified for reason other than cost effectiveness)
		Door or door framing repair
		Storm door
		df2_q54a_03,df2_q54b_03,df2_q54d_03,df2_q54e_03

Ventilation (SF3) – Suppression Factors		
NFIRS		DF2
'132'	'Difficult to ventilate'	Vent damper installed df2_q55e_03
'176'	'Ducts: vertical'	Other ventilation system improvements df2_q57d_03
		Other ventilation system improvements df2_q57e_03
		New duct vents, grills, or registers installed df2_q58c_03
		Whole-house ventilation system df2_q57c_03

Air Sealing (SF4) – Suppression Factors		
NFIRS		DF2
'125'	'Holes or openings in walls or ceilings'	General house caulking and weatherstripping (e.g.,, doors, windows) df2_q51a_03
		Air sealing emphasizing bypasses (leaks identified by auditor and/or crew without using a blower door) df2_q51b_03
		Air sealing emphasizing bypasses (leaks identified by auditor and/or crew with aid of a blower door) df2_q51c_03
		Air distribution system (duct) sealing or repair df2_q51d_03
		Other non-window air sealing work (specify: _______________) df2_q51e_03
		Other non-window air sealing work (specify: _______________) df2_q51f_03

Wall Repair/Insulation (SF5) – Suppression Factors		
NFIRS		DF2
'131'	'Wall collapse'	Wall insulation df2_q52d_03 (normal density)
'137'	'Balloon construction'	df2_q52e_03 (high density)
'181'	'Supports unprotected'	Wall repair df2_q62f_03
		Foundation wall insulation df2_q52h_03

Roof/Attic/Ceiling Repair/Insulation (SF6) – Suppression Factors		
NFIRS		DF2
'112'	'Roof collapse'	Roof repair df2_q62d_03
'121'	'Ceiling collapse'	Attic insulation df2_q52a_03 (none existing)
'161'	'Attic undivided'	df2_q52b_03 (over existing)
'185'	'Wood truss construction'	df2_q52c_03 (existing unknown)
		Ceiling repair df2_q62e_03
		Rim or band joist insulation (sill box) df2_q52g_03

Floor Repair/Insulation (SF7) – Suppression Factors		
NFIRS		DF2
'141'	'Floor collapse'	Floor repair df2_q62g_03
		Foundation repair df2_q62h_03
		Floor insulation df2_q52f_03

Gas (SF8) – Suppression Factors		
NFIRS		DF2
'341'	'Natural or other lighter than air gas present'	Text search in ‘other’ category
'342'	'Liquefied Petroleum (LPG) gas present'	

Summary of Census Data Modification

Zip code level housing counts in this study were derived from four summary tables in US Census Bureau’s Five-Year American Community Survey (ACS) 2008-2012. These data were modified to estimate the desired scope of one- and two-unit homes whose household income is below 150% of the poverty level. Such a modification was necessary as official estimates of this specific scope were not publicly available. The four tables involved were:

- B11011: “Household Type By Units In Structure”
- B25032: “Tenure By Units In Structure”
- B17022: “Ratio Of Income To Poverty Level In The Past 12 Months Of Families By Family Type By Presence Of Related Children Under 18 Years By Age Of Related Children”
- B17017: “Poverty Status In The Past 12 Months By Household Type By Age Of Householder”

A major reason for the need to adjust these tables is disparity between the ACS definition of family type and household type. Household types include three categories of families in addition to nonfamily households, while family types exclude nonfamily households. Ratio of income to poverty level is reported by family type in B17022, which makes a zip code’s number of families below 150 percent poverty readily distinguishable but neglects to include nonfamily households. All household types are listed in B17017 by poverty status, i.e. below or above 100 percent poverty. Modification is thus needed to estimate the number of nonfamily households between 100 and 150 percent poverty. This is done by multiplying the ratio of nonfamily to family households > 100 percent poverty (from B17017) by the number of family households between 100 and 150 percent poverty from (B17022).

In order to only count one- and two-unit households, including mobile homes, it is necessary to multiply each household type by its corresponding proportion of units within this scope. This is achieved by using B25032 to modify B11011. B25032 aggregates unit in structure to three categories: one unit; two or more units; and mobile homes, boats, vans, etc. B11011 lists two-unit households and mobile homes separately, so their ratios of two-unit households to two or more unit households as well as mobile homes to mobile homes, boats, vans, etc. are applied to B25032.