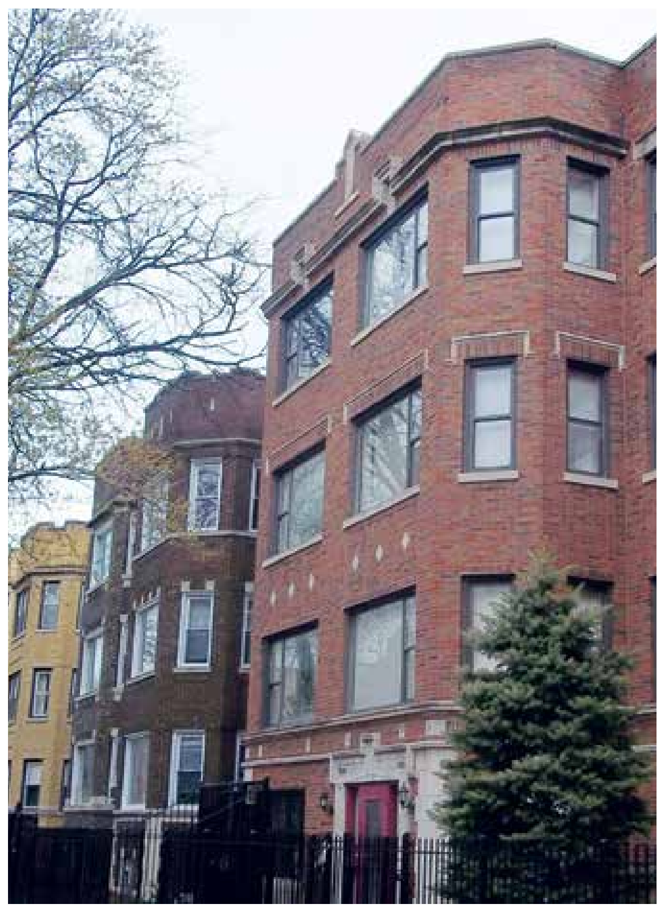
Achieving Health and Social Equity through Housing:

Understanding the Impact of Non Energy Benefits in the United States

Green & Healthy Homes Initiative®



Achieving Health and Social Equity through Housing:

Understanding the Impact of Non Energy Benefits in the United States

AUTHORS

Ruth Ann Norton, *President and CEO*

Brendan Wade Brown, *MHS, Senior Research Associate*

Catherine Lee, *AICP, Outcome Broker*

Kiki Malomo-Paris, *MPP, Public Health and Public Policy Fellow*

Jamal Lewis, *Environmental Health and Policy Fellow*

Green & Healthy Homes Initiative®

1 Introduction

STATEMENT OF PURPOSE

Investments in community-based programs that provide energy efficiency, weatherization or other integrated housing interventions generate non-energy benefits related to improvements in quality, affordability and stability for occupants of low-income housing.

International Energy Agency defines *non-energy benefits, or multiple benefits* as "the wider socio-economic outcomes that can arise from energy efficiency improvement, aside from energy savings".[1] This report uses a social ecological framework to show the pathways linking non-energy benefits to multiple factors underlying the physical and social determinants of health. The report is based on a comprehensive search of peer-review articles from 2000-2016 and summarizes findings on how residential energy efficiency investments in the weatherization of low-income households impacts the affordability of housing by reducing the energy cost burden, and generates greater equity by providing environmental, economic and health benefits for the occupant, owner, local community, region and nation.[2]

This report identifies and explores how home-based energy efficiency measures, weatherization and healthy home upgrades can confer non-energy benefits at the individual and community level, effectively address social determinants of health, and drive significant savings by improving economic, health and environmental outcomes for residents of affordable housing. At the individual level, the occupants of low-income homes experience improvements in housing stability, health, comfort and energy security, and building owners experience less operation and maintenance costs, increased asset values, and decreased vacancy. Benefits also accrue at the community levels through improved air quality and other environmental benefits as well as through macroeconomic benefits related to job and market creation. Government efficiencies and cost savings are possible since the targeting of low-income households provides for an opportunity to address physical and social determinants of health, many of which are leading causes of health inequities, while unlocking the broader savings of non-energy benefits that arise from smart investments in housing.

.

This report identifies and explores how home-based energy efficiency measures, weatherization and healthy home upgrades can confer non-energy benefits at the individual and community level, effectively address social determinants of health, and drive significant savings by improving economic, health and environmental outcomes for residents of affordable housing.

CONTEXT

Many households in the United States are currently experiencing a dual crisis related to the affordability and quality of residential housing.

Unaffordable housing is a both a growing national problem because it affects all Americans and an important social justice issue because it disproportionately affects poor, disabled, elderly, minority, and families with children[3] as well as other vulnerable populations – poor, disabled , elderly, minorities and families with children.[3] Social inequality, related to place of residence, manifest as disparities across a number of population health outcomes and is exacerbated by a number of factors including poverty, housing instability and exposure to unhealthy housing. There is an overall decline in life expectancies in the 21st century despite the increased spending on medical care and it is likely that the inability of the nation to address physical and social determinants of health have contributed to this problem.[4] The solution for this dual crisis, the affordable housing crisis and housing quality crisis, are smart investments in community-based and integrated housing programs designed as public health interventions to deliver energy efficiency and non-energy benefits at the individual level and build resiliency at the community level.

Investments that address social inequities in housing, energy and health are necessary to produce greater affordability, housing stability, energy security, resiliency, health equity and social justice for all Americans.

As the housing stock ages across the nation, there is an increasing need for community-based housing services to maintain, retrofit and upgrade the existing homes to sustain and preserve affordable, quality residential housing. While the current levels of federal and state funding for housing programs such as low-income energy assistance and weatherization services are insufficient to meet the demand, the consequences of inaction ultimately will result in greater inequity and greater costs to local and state budgets. Sustainable green community-based jobs, combined with the delivery of integrated housing services, offer a solution to bring people and communities out of poverty. Investments that address social inequities in housing, energy and health are necessary to produce greater affordability, housing stability, energy security, resiliency, health equity and social justice for all Americans.

ENERGY BENEFITS

There are many U.S. clean-energy initiatives that aim to reduce fossil-fuel usage and produce energy savings through efficiency. These programs can be supply or demand side programs. Supply side initiatives are designed to change the fuel generation supply resources, while demand side initiatives are designed to change end-use efficiency of energy consumption.[5] On the demand side, households spend $230 billion annually on residential energy consumption (not including transportation), which is 22% of total U.S. energy consumption.[6] A McKinsey & Company analysis reported that the residential sector accounts for 35% of the end-use efficiency potential in the US, and estimated energy efficiency investments directed at the residential sector have the potential to save $41 billion annually.[7] Saving energy on the demand side through investments in energy efficiency integrated with health and safety improvements in the existing housing stock can cost less than generating, transmitting, and distributing energy from power plants, in addition to providing multiple health, economic and environmental benefits.[8] A recent analysis of the cost of energy efficiency programs concluded that across the nation energy efficiency remains the lowest-cost resource even as the amount of energy saved has increased significantly – proving consistency and reliability as a long term option.[9] Thus, energy efficiency in the residential sector needs to play a key part of the solution in national, state and local strategies designed to address concerns over housing affordability, future energy supply, energy security and long-term effects of climate change. Yet the potential market for energy efficiency investments in affordable residential housing remains a national resource that is largely untapped and underserved.

Saving energy on the demand side through investments in energy efficiency integrated with health and safety improvements in the existing housing stock can cost less than generating, transmitting, and distributing energy from power plants, in addition to providing multiple health, economic and environmental benefits.

Within the U.S. there is an established practice of valuating the energy benefits—utilization and cost savings—of residential energy efficiency investments. Most energy efficiency programs evaluate energy savings by taking from the baseline energy consumption (costs without improvements) and estimating the difference of the actual energy consumption after the energy efficiency improvements are installed using either deemed or measured approaches.[10] Another impact of energy savings is greater regional or national energy security that occurs when energy efficiency investments result in protecting electricity producers and consumers from the costs of adding new capacity to the system and from energy supply disruptions, volatile energy prices, and other reliability and security risks.[11] Both energy saving and national energy security have a well-known evidence base of research and therefore remain outside of the scope of this research project.

NON-ENERGY BENEFITS

The International Energy Agency defines non-energy benefits as "the wider socio-economic outcomes that arise from energy efficiency improvement, aside from energy savings".[12] Non-energy benefits are the direct outputs, outcomes or impacts produced at different levels of the economy: at the individual level (individuals, households and enterprises); at the sector level (by economic sector such as transport, residential, and industrial sectors); at the national level (including macro-economic benefits, and benefits to national budgets); and at the international level (reflecting the international public good of these benefits).[13] In the US, the non-energy benefits of energy efficiency programs have been narrowly defined in terms of greenhouse gas (GHG) emissions reductions because they are easily calculated and also because other non-energy benefits have been difficult to measure until recently. Over the past two decades, in part to meet federal air quality standards, states have increasingly included reduction in greenhouse gas emissions and criteria air pollutants as part of their energy policy planning process, as well as state development and economic goals. Although many states are starting to incorporate the benefit of reducing carbon monoxide into energy policy economic calculations and decision making, many state-level clean energy analyses currently do not quantify emission-related health effects. Innovative policies designed to implement integrated housing programs are necessary to achieve both energy, housing and public health goals and provide measurable outcomes to bridge the valuation gap created by not incorporating non-energy benefits in analysis and evaluation practices.[14]

International Energy Agency defines non-energy benefits as "the wider socio-economic outcomes that arise from energy efficiency improvement, aside from energy savings".

Over the past 25 years, there has been significant progress in the identification and measurement of other non-energy benefit categories, especially those that stem from weatherization of residential homes. The non-energy benefits attributed to energy efficiency and weatherization are traditionally organized according to level of economic

impact. IEA classifies non-energy benefits at the individual levelas benefits of health, comfort and energy security that accrue to the occupants, and reduced operation and maintenance costs, increased asset values, and decreased vacancy experienced by by the building owner. At the sector level, the benefits accrue either to the utility as industrial productivity and infrastructure benefits or to the ratepayers as reduced energy costs and neighborhood stabilization. At the national level the benefits accrue to society as improved environment and air quality, and macroeconomic benefits related to job and market creation. In the US, non-energy benefits are similarly classified according to benefits that accrue to households or program participants (occupant and/or owner), utility and ratepayer benefits and societal benefits- which correspond respectively to the IEA's individual, sectoral and national classification typology.[15] **Table 1** presents the different non-energy benefits identified by IEA and U.S. typologies that are then organized by economic level. Findings in this report are organized to provide a greater focus on individual level benefits for occupants and homeowners, specifically on environmental and health outcomes of occupants attributed to weatherization and energy efficiency improvements of residential housing- while still providing an overview on the community benefits that are produced at more distal sectoral and national levels.

Within affordable housing many of the non-energy benefits uniquely accrue at the individual level to individual single family homeowners or both owners and occupants of rental units (see Table 1). These individual level benefits are realized through many pathways including increased wealth retention, energy security, renter affordability, improved energy efficiency, water conservation, and health and safety in existing single and multifamily housing. However, many low and extremely low-income households that would benefit the most from energy savings are the least likely to be able to afford such energy efficient home improvements. Low-income families are less likely to have energy efficient appliances, more likely to live in older, less efficient homes and are 25% more likely to have energy intensive heating and cooling systems.[16] Exacerbating the challenges for such lower-income households are siloed, fragmented, and increasingly cash-strapped government programs that are designed to alleviate or remedy housing-related energy burdens (i.e. utility costs a percentage of gross income).

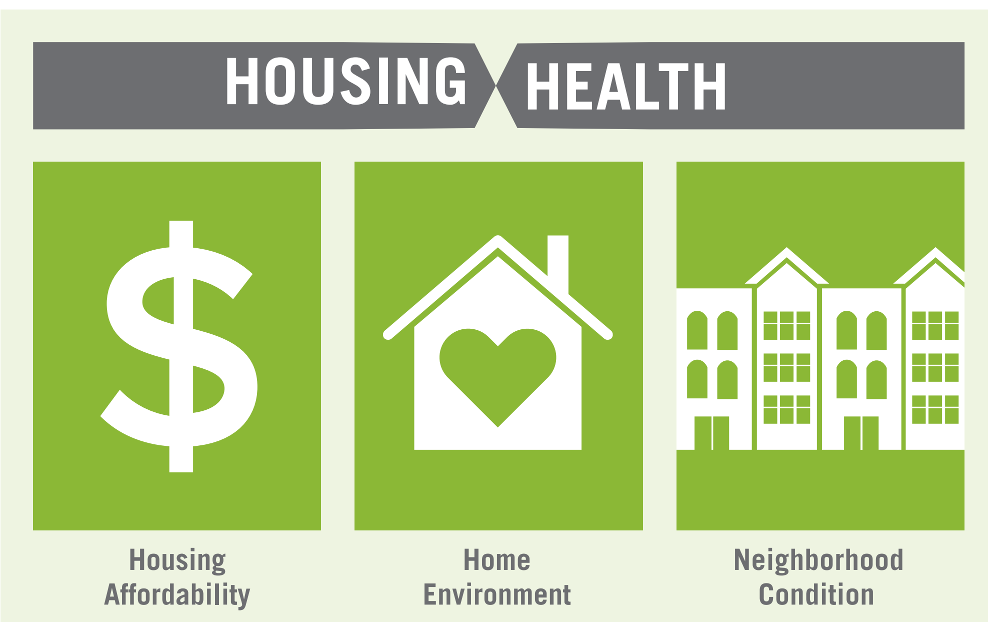
Low-income families are less likely to have energy efficient appliances, more likely to live in older, less efficient homes and are 25% more likely to have energy intensive heating and cooling systems.

For example, the Low-income Home Energy Assistance Program (LIHEAP) reaches under 25% of eligible households that are eligible for the program.[17] In FY2009, an estimated 35 million households were eligible for LIHEAP under the federal statutory guidelines, however, only 7.4 million households received heating or winter crisis assistance and approximately 900,000 households received cooling assistance.[18] Similarly in 2008, it was reported that close to 35 million households were income-eligible for the Weatherization Assistance Program (WAP), representing approximately 30% of U.S. households.[19] Historically, the national WAP serves an average of 100,000 households per year with a budget of approximately $200 million. Research demonstrates that energy efficiency measures are not only a low-cost energy resource for the nation, but also has the potential to be a source of sustainable reinvestment in communities to maintain low-cost housing and support positive social outcomes.[20] By creating a better understanding of the health, economic and social impacts of non-energy benefits, this report aims to explain the full value and impact of energy efficiency investments in weatherization and healthy home interventions directed towards improving the quality of life for low-income households.

PATHWAY LINKING NON-ENERGY BENEFITS TO THE SOCIAL DETERMINANTS OF HEALTH

Social determinants of health (SDOH) are defined by World Health Organization (WHO) and by Healthy People 2020 as the conditions in the environments in which people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks.[21]

Housing research generally shows that the link between housing and health outcomes are known to include three inter-related aspects: housing affordability, conditions of the home environment, and conditions of the neighborhood, which also affect the overall ability of families to make healthy choices.[22] Social and economic factors, such as affordability, restrict housing and neighborhood options for low-income households and energy insecurity that leads to utility shutoffs and forces tradeoffs in meeting basic needs such as housing, food and health care.[23] Location also matters as affordable housing is often located in the context of built environments existing within or contiguous to poor neighborhoods with limited resources and social capital. The factors of housing quality



and environmental conditions are often the result of a legacy of social and environmental injustice which systematically has led to increases in low-income residents' risk of exposure to housing-related health and safety hazards, energy insecurity and fuel poverty. These accumulated negative conditions and disinvestment in low-income neighborhoods result in greater social inequities of health and lower life expectancies for the residents. Across generations these inequities cluster and accumulate over people's lives and cumulatively over time diminish the ultimate quality and length of life in these neighborhoods.[24]

The factors of housing quality and environmental conditions are often the result of a legacy of social and environmental injustice which systematically has led to increases in low-income residents' risk of exposure to housing-related health and safety hazards, energy insecurity and fuel poverty.

Physical and social determinants of health impact every person, yet health equity research shows that "health, disease and death are not randomly distributed".[25] In fact physical and social determinants of health are place-based and therefore illnesses concentrate among residents of low-income neighborhoods due to the existing health inequities caused by social inequalities. Health inequities are systematic differences in the opportunities by which groups can achieve optimal health, leading to unfair and avoidable differences in health outcomes.[26] In the United States, the burden of disease and poor health and the benefits of well-being and good health are inequitably distributed. Place matters to such an extent that where one lives in the United States determines an individual's life expectancy.[27] Research into population health has consistently demonstrated the association between health status and socioeconomic status tends to produce a social gradient of unequal health outcomes which results in the most advantaged in society having better health status, and the least advantaged more likely to have worse health status. Although some aspects of a person's health status depend on individual behaviors and choice, health is also shaped by community-wide factors. Research shows that physical and social determinants of health such as poverty, unemployment, low educational attainment, inadequate housing, lack of public transportation, exposure to violence, and neighborhood deterioration shape health and contribute to ongoing health inequities.

Accordingly, Healthy People 2020 organizes the social determinants of health into a place-based framework with the five key domains and their underlying factors as follows:

Economic Stability–poverty, employment, food security, and housing stability;

Education–HS graduation; enrollment in higher education; language/ literacy; early childhood education and development;

Social and Community Context–social cohesion, civic participation, perceptions of discrimination and equity, and incarceration/ institutionalization;

Health and Health Care–access to health care, access to primary care and health literacy;

Neighborhood and Built Environment–access to healthy foods, quality of housing, crime and violence, and environmental conditions.[28]

In total, this report identifies 38 Healthy People 2020 objectives and three leading health indicators that are impacted by integrated housing interventions summarized in **Table 2**. Thus, integrated housing measures would not only support the National Prevention Strategy to achieve Healthy People 2020 goals, but are vital mechanisms to transform the U.S. into a prevention-oriented society that employs public health best practices, and integrates health and health equity criteria across multiple sectors, specifically in regards to affordable housing, community planning and energy policy decisions.[29] Investments in energy efficient, safe, affordable housing for low-income communities can be directed to re-establish social equity in health by reducing the excess of housing and energy burdens experienced by these populations. There are many complex social problems that have no immediate solution, however the opportunity to perform energy upgrades and environmental remediation of the existing housing stock presents an immediate solution to both the housing and energy burden of many households.. There are a lot of social problems that can only be addressed in ways that cost industry money or lower profits. While there are only a few examples where solving the social problem will make an industry more profitable.

The inability of local housing markets to equitably provide adequate number and equal access to affordable, quality housing is a national problem that requires a community-based solution.

Across the U.S low-income communities are frequently severely deficient in at least the Neighborhood and Built Environment, if not all, of the key domains of SDOH. Furthermore, the occurrence of a deficiency in one key area negatively affects standing in another. Often in the U.S. housing market, the most vulnerable populations (elderly, families with children, and persons with disabilities) are living in neighborhoods and built environments with multiple deficiencies, including poor education or job training opportunities, lack of amenities, unemployment and job insecurity, poor working conditions and unsafe neighborhoods.[30] The inability of local housing markets to equitably provide an adequate number of and equal access to affordable, quality housing is a national problem that requires a community-based solution. A community-based solution is an action, policy, program, or law that is driven by the community and its members to affect local factors that can influence health, and has the potential to promote health equity.[31]

CONCEPTUAL PATHWAY LINKING NON-ENERGY BENEFITS TO SOCIAL DETERMINANTS OF HEALTH

Inputs

COMPREHENSIVE HOUSING INTERVENTION

Energy Efficiency
Weatherization
Healthy Homes

Direct Energy Outputs

Change in kWh supplied

Change in kWh consumed

Energy Benefits

Reduce energy demand

Demonstrate leadership

Non Energy Outputs

Air Quality

Reduce criteria air pollutants

Reduce GHG emission

Health

Improved fire safety

Thermal comfort

Better Indoor air quality

Reduced environmental toxins

Economic

Displacements savings from energy cost and waste heat

Program costs

Sector transfers

Non Energy Benefits

Environmental

Reduce GHG

Improve IAQ

Direct Occupant Health

Changes in incidences of:

Mortality

Hospital admissions

Upper & lower respiratory illness

Asthma/COPD

Lead poisoning

Cancer

Skin and eye irratation

Cardio-vascular disease

Depression and anxiety

Macro-Economic

Employment

Gross state product

Economic output & growth

Personal income/savings

Direct Economic

Individual:
Reduce energy cost

Reduce reliance on energy assistance programs

Reduce risk of eviction

Community:
Increase home values

Preserve affordable units

Long Term Impacts

Neighborhood & Built Environment

Quality of housing

Environmental conditions

Crime and violence

Health & Health Care

Access to health care

Access to primary care and health literacy

Social & Community

Social cohesion

Civic participation

Perceptions of discrimination and equity

Incarceration/institutionalization

Education

Early childhood education and development

School attendance

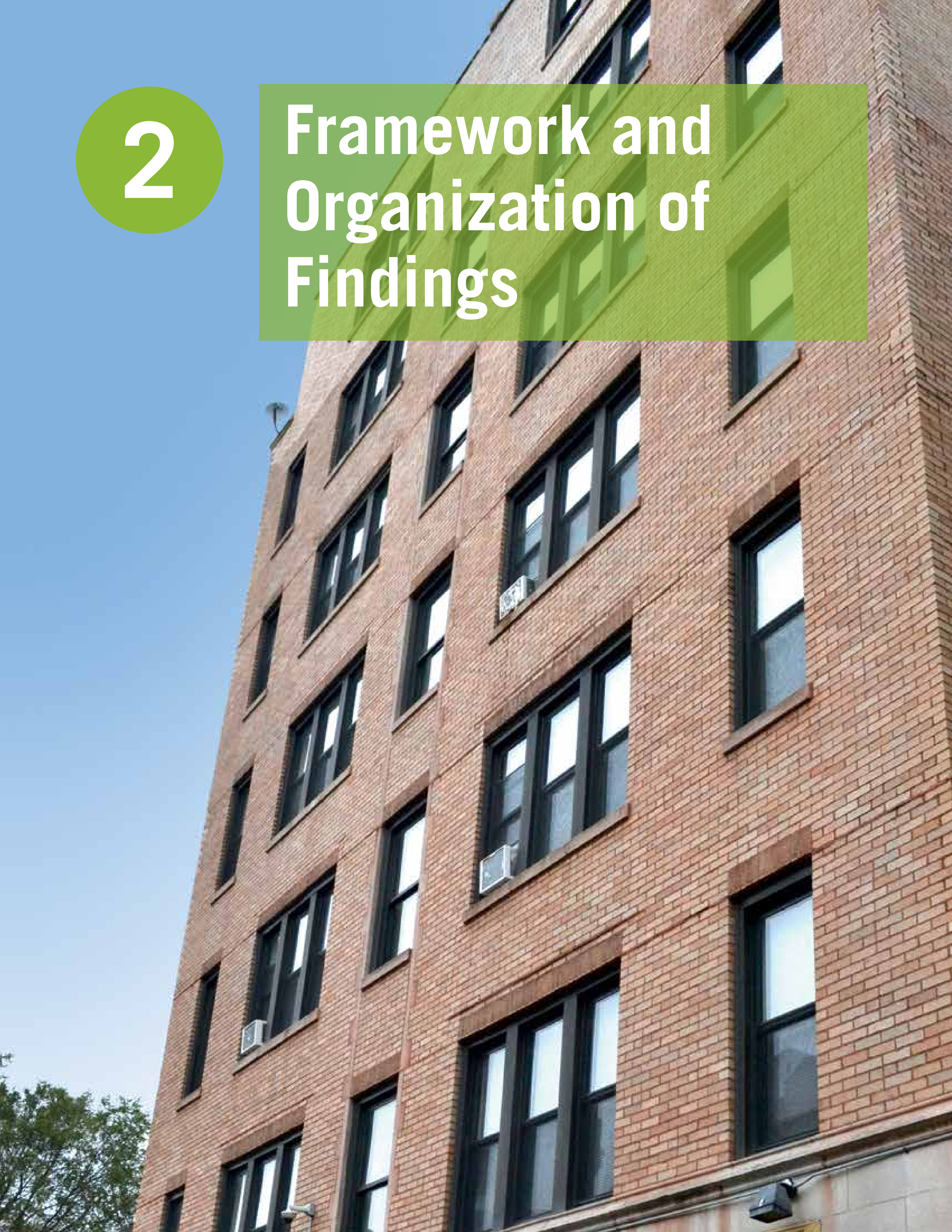
Economic Stability

Poverty

Employment

Housing stability

2 Framework and Organization of Findings



AN ECO-SOCIAL FRAMEWORK LINKING NON-ENERGY BENEFITS TO SOCIAL DETERMINANTS OF HEALTH

The eco-social theory of the distribution of disease maintains social conditions are leading factors underlying the inequitable distribution of disease which in turn manifest as social inequalities in health among populations.

"Social inequalities or social inequities in health refer to health disparities within or between countries that are unfair, unjust, unavoidable, and unnecessary (neither inevitable nor un-remediable) and that systematically burden populations rendered vulnerable by underlying social structures".[32] Since many health outcomes are in part generated by social conditions, such as housing affordability and quality, we find it necessary to establish a framework showing the non-energy benefits pathway linking to impacts on SDOH. The framework intends to show the multiple pathways by which non-energy benefits directly impact both by improving the quality of housing and affordability of housing by reducing the energy and housing cost burden. These non-energy benefits in turn generate greater social equity in health by providing environmental, economic and health benefits for the occupant, owner, and community.[33]

Since many health outcomes are in part generated by social conditions, such as housing affordability and quality, we find it necessary to establish a framework showing the non-energy benefits pathway linking to impacts on SDOH.

Overall the research findings, and particularly results from the National Weatherization Assistance Program National Evaluation,[34] show energy interventions alone can generate many of these non-energy benefits. Findings presented in this report demonstrate that implementing integrated "green and healthy home" interventions that combine healthy housing, warmth and energy efficiency measures with resident education can lead to greater improvements in health equity, especially when interventions are targeted at those with existing health problems living in inadequate housing conditions.[35] Policies that facilitate such investments into low-income communities are the type of home-based population health prevention strategies that are necessary and sufficient to directly impact three categories of SDOH: health and health care, economic stability, and neighborhood and built environment. In addition, the research findings show evidence that housing affordability and quality indirectly lead to positive impacts related to housing stability, education (attendance, performance and attainment), and improved mental health from reducing stress of household occupants.[36] **Figure 1** illustrates the pathway by which evidence-based housing interventions that combine healthy housing, energy efficiency and weatherization measures can produce non-energy benefits that impact SDOH.

ORGANIZATION OF FINDINGS

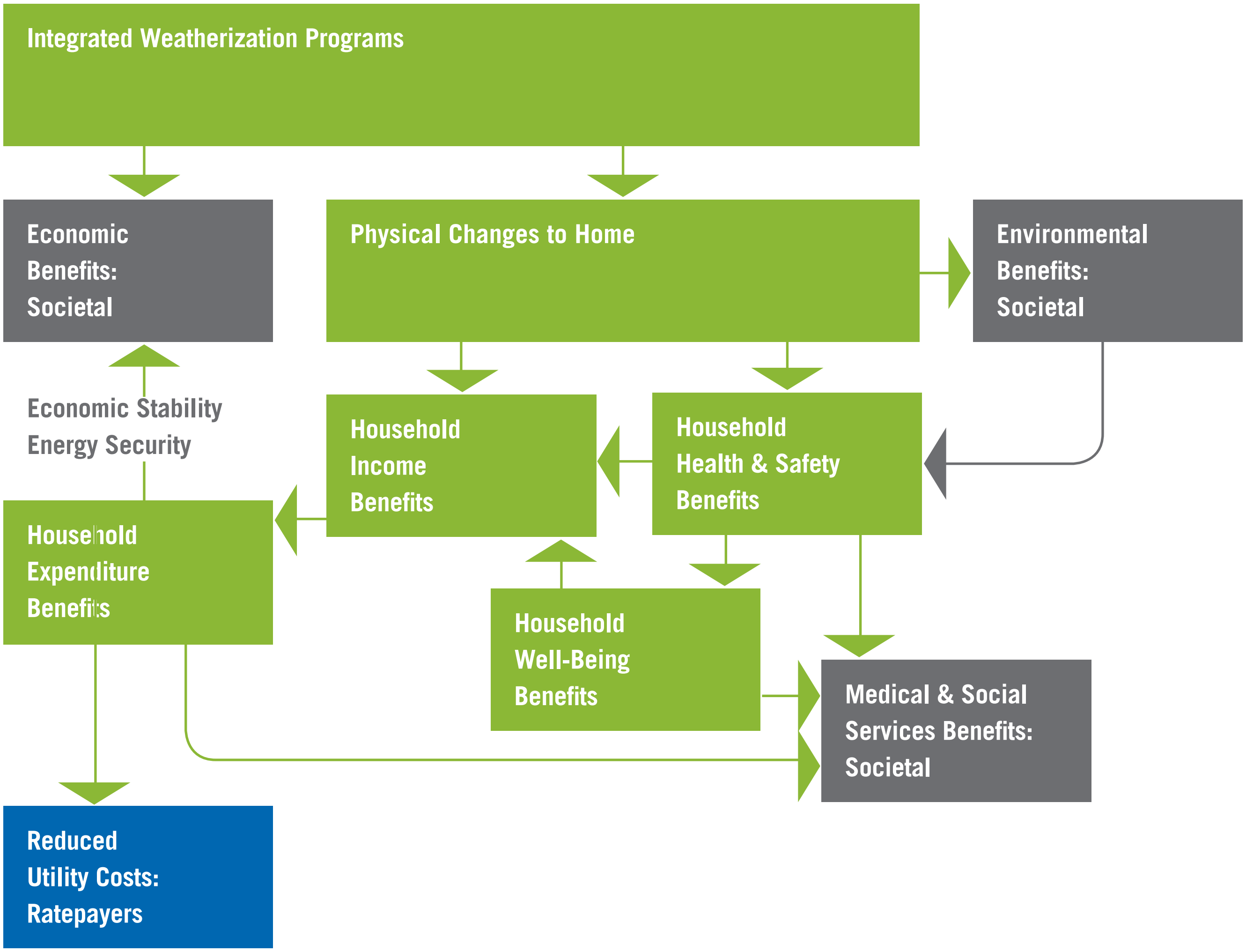
As previously asserted, the non-energy benefits associated with housing intervention that result from the integration of energy efficiency, weatherization and healthy homes best practices can effectively mitigate negative impacts of poor quality housing and housing (including rent and utility) cost burden.

Integrated housing interventions also impact different sectors at different levels of the economy. The social ecological framework guides how the findings are organized to account for various benefits produced by integrated housing interventions at different economic levels (individual-level, community-level and national-level). Since the focus of the report is individual or household level benefits, each section that outlines the individual or household-level impacts is organized by: identifying the health hazard or economic burden that are caused by poor quality and unaffordable housing, presenting evidence of the impact, introducing the best practices of integrated interventions that address these physical and social determinants of health, and quantifying the non-energy benefits that are accrued as a result of the integrated interventions.

At the individual or household level an occupant directly benefits from residential home improvements since they experience improved quality of indoor environmental conditions, greater energy security and household economic stability. By addressing housing affordability – energy efficiency or integrated home interventions directly impact **Economic Stability** factors at the household level (income benefits, energy security, food security and housing stability) and community level (poverty and employment). Household income and expenditure benefits are presented in the section on *Impact of Housing Affordability.*

Similarly, by addressing energy inefficiencies, health and safety hazards within the home-energy efficiency or integrated home interventions directly impacts **Neighborhood and Built Environment** factors – quality of housing and environmental conditions at the

WEATHERIZATION WORKS: FRAMEWORK FOR UNDERSTANDING NON-ENERGY BENEFITS



individual level. Household health and safety benefits are presented in the section on *Impact of Poor Quality Housing on Occupant Health.*

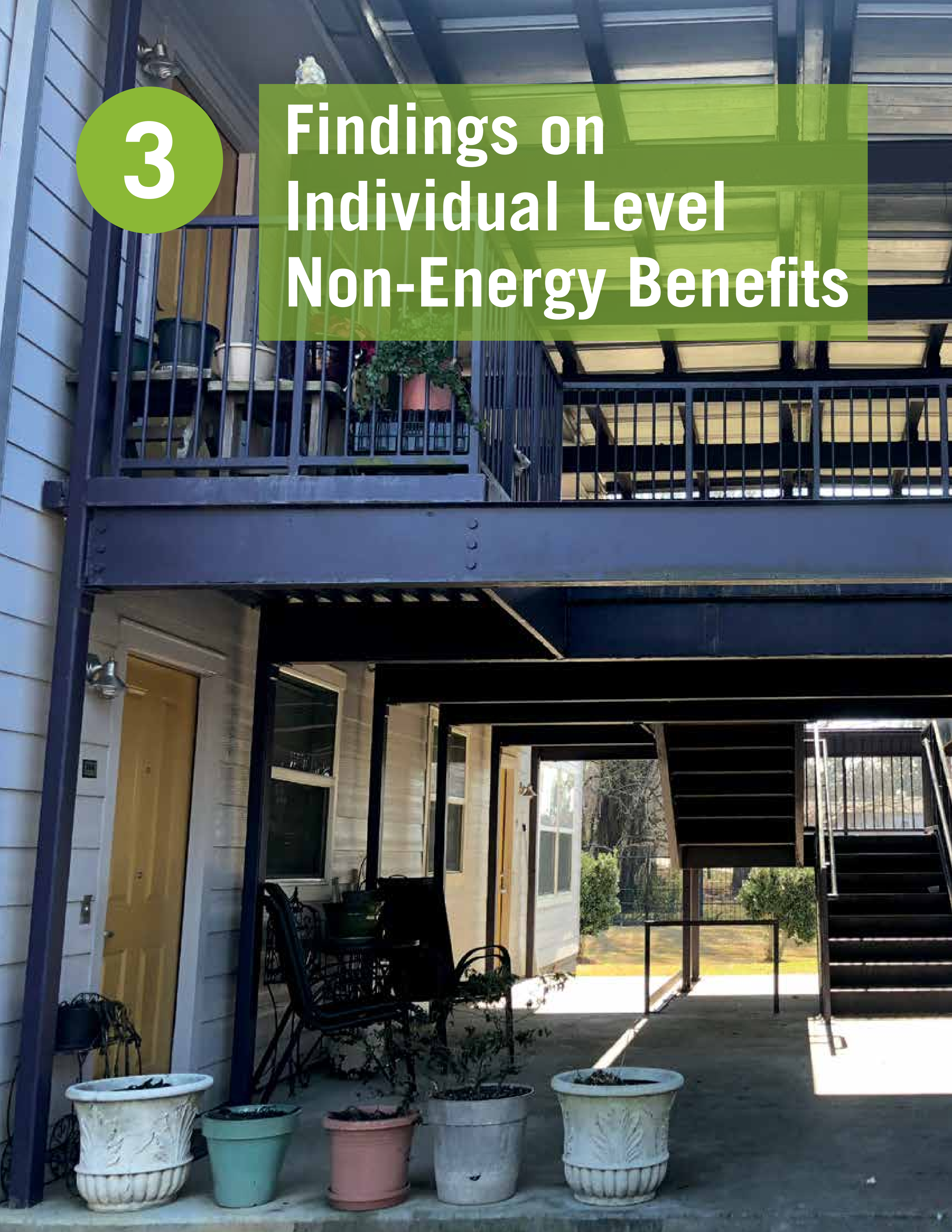
The indirect impacts of experiencing healthy built environment and greater energy security leads to housing stability, improved well-being and mental health at the household level, as well as productivity improvements related to education and employment at the community level. Indirect impacts on residential occupants are presented in the section on *Indirect Impacts on Occupants.*

Individual level benefits also accrue to homeowners or multi-family building owners such as reduced operation and maintenance costs, deceased vacancy rates and improved property asset values. These benefits are presented in the section on *Impact on Owners of Multi-Family Units.*

Community level benefits, which include preserving affordability of existing housing stock and increasing neighborhood stabilization and resiliency; Sectoral level benefits, which include infrastructure advances and large-scale benefits to developers and ratepayers; and national level benefits, which include job creation and other macroeconomic benefits are all discussed in the section on *Findings on Impacts at the Community and National Level.*

As previously asserted, the non-energy benefits associated with housing intervention that result from the integration of energy efficiency, weatherization and healthy homes best practices can effectively mitigate the negative impacts of housing (and rent) cost burden and poor quality housing. Integrated housing interventions also impact different sectors at different levels of the economy. The following sections will review the non-energy benefits produced by integrated housing interventions at the individual level, beginning with the impacts on occupant health. Thereafter the report will review the remaining individual level non-energy benefits and provide an overview of community level benefits.

3 Findings on Individual Level Non-Energy Benefits



IMPACT OF HOUSING AFFORDABILITY

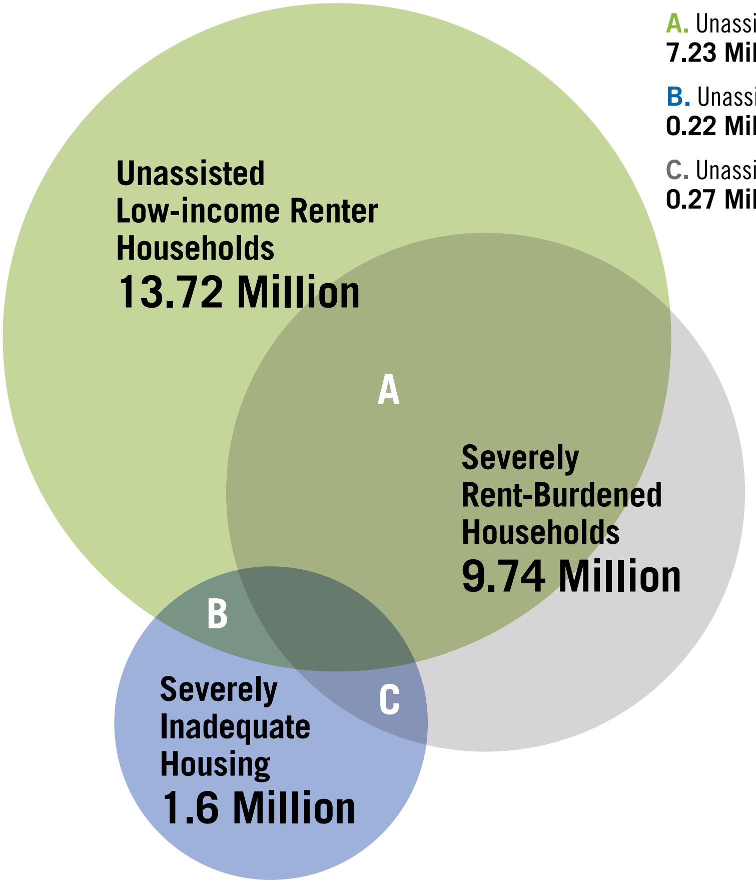
For over four decades most urban housing markets in the U.S. have failed to produce an adequate supply of quality affordable housing for low-income households.[37]

The sharp economic downturn during the 2007-2009 recession, which resulted in high unemployment, declining rates of homeownership, and greater disinvestment in minority and low-income neighborhoods, has since led to lower homeownership rates among low-income households and a shortage of affordable rentals.[38] Overall the amount of real home equity fell from $14.9 trillion at its peak in the first quarter of 2006 to $6.3 trillion at the end of 2010.[39] The foreclosure crisis has accelerated the declines in the rate of homeownership, particularly among minorities and households with children, with black households experiencing nearly twice the decline compared to white households from 2004-2011.[40] Many of these same families have also faced a "decade-long stagnation of household incomes and erosion of wealth – especially housing wealth (loss of home equity), which has contributed to a steep rise in the share of households spending more than half their incomes on housing" (i.e. severe housing burden).[41]

A recent How Housing Matters survey finds a majority of the American population (81%) believe housing affordability is a problem and among those surveyed 16% of adults feel only somewhat stable and secure or unstable and insecure in their current housing situation – which represents more than 37 million Americans.[42] The same survey reported many groups were experiencing housing vulnerability at especially high rates, including 33% of renters, 42% of distressed renters (those who spend more than 30% of their income on rent), 30% of adults with income less than $40,000, 23% of adults with a high school degree or less education, 34% of African Americans, 24% of Hispanics, and 23% of city dwellers.[43]

A recent How Housing Matters survey finds a majority of the American population (81%) believe housing affordability is a problem and among those surveyed 16% of adults feel only somewhat stable and secure or unstable and insecure in their current housing situation – which represents more than 37 million Americans.

Over the past two decades the affordability crisis has placed an inequitable distribution of the housing burden on vulnerable populations, such as those with extremely low-incomes, minorities, low educational attainment, and renters. In particular for households dependent on the rental market, the recession and financial crisis sharply



WORST CASE HOUSING NEEDS – 7.72 MILLION

A. Unassisted LI Renter + Severely Rent-Burdened
7.23 Million

B. Unassisted LI Renter + Severely Inadaquete
0.22 Million

C. Unassisted LI Renter + Severely Rent-Burdened + Severely Inadaquete
0.27 Million

Source: U.S. Department of Housing and Urban Development "Worst Case Needs Report to Congress". HUD PD&R 2015
https://www.huduser.gov/portal/Publications/pdf/WorstCaseNeeds_2015.pdf

reduced the available options for affordable rental housing.[44] As a consequence of the lower homeownership rates, rental housing markets are experiencing a structural readjustment where a shortage of available affordable rental units coincides with increased demand resulting in higher rents.[45] Widespread wage stagnation, decreasing supply, and greater demand for affordable rental housing have negatively impacted households experiencing either a moderate to severe housing or energy burden (the utility bills as percentage of income); usually both. In 2014 52.3% of renters and 35.6% of homeowners with mortgages were classified as having a moderate or severe housing cost burden.[46] For renters, nearly 84% of households earning under $15,000 and 77% of households earning between $15,000 and $29,000 experienced at least a moderate housing cost burden.[47] Thus the housing affordability crisis is worse among those very low- and extremely low-incomes renters, particularly as potential homeowners remain displaced in the rental market.

	Average Sales Price for New Homes Sold	Annual Income Needed to Afford New Housing	Rate of Cost Burdened Renters (30% or more of income)	Rate of Cost Burdened Households with rent or mortgages (30% or more of income)
2000	$207,000	$61,040	36.85%	33.87%
2005	$297,000	$70,240	45.68%	39.22%
2010	$272,900	$56,560	50.85%	42.97%
2015	$360,600	$67,640	51.80%	41.13%

Sources: Column A) U.S. Census Bureau, New Residential Sales Historical Data, "Median and Average Sales Prices of New Homes Sold in United States;" Column B) Estimates of annual income needed for mortgage payments to be 30% of monthly income based on Total Average Sales Price for New Homes Sold. Mortgage payment estimates based on Freddie Mac Historical Data for Annual Averages of 30-year Mortgage Rates; Columns C & D) American Community Survey 5-Year Estimates (2011-2015, 2006-2010, 2001-2005, and 1996-2000).

COST BURDENED HOUSEHOLDS

Despite increases in fair housing policies and targeted resources for low-income households, the housing market still falls short of addressing the affordable housing gap. Unlike other commodities, housing does not necessarily depreciate by age, with historic housing often carrying additional value. Property values are also relative to neighborhood standing in the market, not just the condition of structure or size of lot.[48] Additionally, some households occupy housing that is below the value of what they can afford, reducing supply available to low-income households.[49] The process of real estate filtering provides an inadequate supply of affordable housing and, in most local and regional housing markets, increases the housing cost burden for the majority of low and moderate income households. Two of the most important factors contributing significantly to the affordability gap are household incomes and housing prices; first, most households wages have stagnated in recent years, and second, new housing construction focuses on developing housing units for the wealthy, not the middle class.[50] A recent Department of Treasury report on economic security concludes the combination of rising wage inequality and changing household structure has produced higher levels of household income inequality since economic gains over the past four decades have not been broadly shared.[51] As a result, housing prices relative to household income have risen dramatically in the past two decades, and the rates of cost burdened households for both homeowners with mortgages and renters have increased (see table above).[52]

The increase in housing cost burden rates have persisted even during the Great Recession when there was a short period of dramatic decline in housing prices driven by a fourfold increase in the rate of foreclosure starts and high unemployment.[53] Also as a result of the Great Recession, the number of renters has increased and vacancies decreased, which in turn is driving up the proportion of low-income households who are severely rent burdened (i.e., pay more than 50% of their incomes for rent).[54] For Black and Hispanic households, the Great Recession has led to historic equity losses that were particularly severe and subsequently sharp declines in the rate of homeownership.[55] Another recent study by the Pew Research Center found that median wealth fell by 66% from 2005 to 2009 among Hispanic households and 53% among Black households, as compared with just 16% among White households.[56] Households with housing cost burdens, especially those most directly impacted by the recent foreclosure crisis and long term affordability crisis, can also experience cost burdens related to the housing instability they experience. According to the Department of Housing and Urban Development, most blatant forms of housing discrimination have declined since the first national paired-testing study in 1977, but many forms of discrimination still persist and raise the costs of housing search for minorities and restrict their housing options.[57]

On average, U.S. communities have 35 affordable and available units for every 100 extremely low-income renter households, though some metropolitan areas experience greater scarcities in affordable housing.

As such housing burden, which is the most recent addition to the 46 Healthy People 2020 topics that set the objectives, measures and targets for national public health goals, is now included among the SDOH indicators. These new indicators are selected and organized using a Health Determinants and Health Outcomes by Life Stages conceptual framework, and are a foundational resource supporting the National Prevention Strategy designed to achieve Healthy People 2020 goals.[58] In fact, Healthy People 2020 tracks two measures that are important indicators of housing affordability: 1) **moderate housing burden**- "Proportion of households that spend more than 30% of income on housing" and 2) **severe housing burden**- "Proportion of renter households that spend more than 50% of income on housing" are two sub-indicators within Economic Stability determinate category.[59] Poverty and Food Security are two other important indicators included in this new area of public health concern, which are deemed necessary to meet population health goals. Poor populations are at particular risk of experiencing a housing burden related to energy cost burden and unhealthy housing. Energy is known to directly impact food security.[60]

Occupation of inadequate, inefficient housing with hazardous conditions is increasingly common for low and moderate income households due to the limited availability of housing stock that is affordable to these groups.[61] Very low-income (VLI) households are those with income between 31 and 50% of Area Median Income (AMI), while extremely low-income (ELI) households are those with income at or below the poverty guideline or 30% AMI. Analysis of the most recent American Community Survey shows that ELI households, who are more likely to be experiencing wage stagnation, face a shortage of 7.4 million rental units. Seventy-one percent of ELI renter households spend more than half of their income on rent and utilities.[62] The standard definition of moderate and severe housing burden is respectively spending greater than 30% and 50% of household income on housing costs. In the U.S. the housing burden is a growing problem for many Americans, but especially very low and extremely low-income.

Every major metropolitan area in the nation has a shortage of affordable and available rental homes for ELI renters. On average, U.S. communities have 35 affordable and available units for every 100 ELI renter households, though some metropolitan areas experience greater scarcities in affordable housing. Households face the largest relative shortages in communities where housing markets have been destabilized due to the late 2000s housing market crash, rapid population growth, or increasing income inequality. Cost burdened renters are often forced to trade payments for housing costs with other family financial needs, including food, healthcare costs, transportation, retirement savings, and other basic necessities. Low-income renters with severe cost burdens are most likely to reduce spending on food and transportation in order to pay rent.[64] Severely cost-burdened renters in the lowest quartile of expenditures spend 41% less on food and health care than similar households who are not cost- burdened.[65]

Of all at-risk renters with housing needs-including the elderly, people with disabilities, and working poor families with children-75% receive no federal assistance to address their cost burdens.

Rental assistance programs, including project-based public housing and voucher programs, have been shown to effectively reduce housing cost burdens and improve housing stability for low-income households, but these programs are not currently meeting need in communities across the nation. In recent years a significant amount of public investment in housing has gone to higher-income homeowners rather than low-income renters.[66] According to the Center on Budget and Policy Priorities, in 2015 the federal government spent $150 billion to subsidize housing in the U.S. for both renters and homeowners, with "a disproportionate share of subsidies on higher-income households and they favor homeownership over renting."[67] Research on the full range of housing subsidies across federal agencies shows that public investments largely support homeownership for higher income households, while only one in four low-income households, which are more likely to be cost-burdened, receive the rental assistance for which they are eligible.[68]

As of 2013, at least $70 billion a year in federal funding was spent on the mortgage interest deduction, one of the largest single federal tax expenditures. In 2012, 77% of the benefits went to homeowners with incomes above $100,000.[69] Meanwhile, rental assistance programs have been underfunded. Due to caps on spending for non-defense discretionary programs, funding for rental assistance has been reduced as the affordable housing crisis has worsened in the 2010s.[70] Most jurisdictions are experiencing a housing affordability crisis, with low and very-low-income households struggling to find available and affordable housing units. Though these families are technically eligible for housing assistance, waitlists for rental assistance programs are either years in length or closed entirely. Of all at-risk renters with housing needs-including the elderly, people with disabilities, and working poor families with children-75% receive no federal assistance to address their cost burdens.[71]

MINORITIES AND HOUSING DISCRIMINATION

Public policy interventions designed to address shortages of affordable housing stock and reduce housing cost burdens for low-income households recognize that the real estate market process of filtering does not completely address housing affordability needs in the nation. Despite the Federal Housing Administration's (FHA) purpose of increasing affordability of homeownership for the growing middle class, housing discrimination undermined the filtering process and kept millions of households from homeownership opportunities. For example, the FHA implemented redlining, a practice in loan underwriting that required applicants to live in racially homogenous neighborhoods, newer housing structures, and gave preference to men with white collar jobs.[72]

By denying access for non-white households to mortgages subsidized by the FHA, and in neighborhoods and communities with racial diversity and older housing, the federal government introduced systematic racial bias into the filtering process. Neighborhood neglect in central cities and in majority non-white neighborhoods worsened as metropolitan areas grew. The practice of redlining, in combination with local segregation laws, kept financial investments out of neighborhoods occupied by racial and ethnic minorities, suppressing the potential market value for the housing they occupied and blocking access to resources for housing revitalization.

Through adoption of the Federal Fair Housing Act in 1968, the federal government expressly prohibited racial discrimination in the housing market, and has expanded protections to other vulnerable groups in subsequent years. Despite the increase of fair housing laws, a lack of enforcement limits control of housing discrimination and allows its persistence.[73] As a result, the federal government has created housing programs and funding resources to better serve households who are likely to experience discrimination and cost burdens, such as people with disabilities and veterans. Many of these programs, from project based housing developments to housing choice vouchers, expressly serve low-income renters. The largest resource for the development of affordable rental housing comes from the Low-income Housing Tax Credit Program, created in 1986, which creates market-based incentives for investments in housing developments that are affordable to cost burdened households.[74]

Still, more programs and resources are needed to promote housing affordability and improve housing quality for minorities and low-income communities. Programs that encourage investments in energy efficiency, weatherization, and healthy homes improvements targeted at low-income communities can be a step towards overcoming structurally racist housing policies that have persisted through time and contributed to the underdevelopment of these communities.

Despite the increase of fair housing laws, a lack of enforcement limits control of housing discrimination and allows for its persistence.

RENTERS VS HOMEOWNERS

Homeownership has been a goal of national housing policy since the post-World War II era, while public policies and programs that support rental housing are typically created to meet needs of families or individuals who are most likely to experience poverty and homelessness (families with children, the elderly and disabled).[75] Reasons for the emphasis on homeownership in housing policy range from personal financial benefits of wealth accumulation and housing cost stability to social and societal benefits. As the U.S. experienced rapid urbanization in the 20th century, municipal development stakeholders valued homeownership because of its perceived impact on social stability, community investment, and even crime rates.[76] However, following the subprime mortgage crisis of 2007-2010 there has been noted a dramatic change in both the rates of homeownership and the discourse on the risks of homeownership. Housing market analysis shows that in the aftermath of the housing market bust, low-income and minority households have experienced both greater wealth loss in the homeownership market and less access to affordable housing in the rental market.[77]

Housing market analysis shows that in the aftermath of the housing market bust, low-income and minority households have experienced both greater wealth loss in the homeownership market and less access to affordable housing in the rental market.

Plummeting homeownership rates in the 2010s have increased the overall demand for affordable rental homes among all working class families.[78] The surge in demand has contributed to the recent decline in the overall rental vacancy rate—from 10.9% in 2009 to 8.4% in 2013—rates not seen since the early 2000s. Multifamily housing in buildings with at least five units (42 % of the rental housing) has a 9.1% national vacancy rate.[79] The combination of increasing demand for rental housing and increasing costs of rent has resulted in a tightening of the rental market that creates significant cost burdens for low-income households and limited accessibility to quality housing.[80]

Rising values within the rental market can also cause displacement of low-income renters. Matthew Desmond's 2016 publication, Evicted: Poverty and Profit in the American City, details the many ways in which highly competitive rental markets can lead to steep rent increases and evictions. Millions of households are forced out of rental housing each year, often with additional burdens of debt related to rent owed to previous landlords or delinquent utility accounts, as well as loss of security deposits.[81] Given that nearly one third of all renters move each year, and low-income renters are the most mobile households nationally, housing discrimination can significantly limit affordable housing choices and raise the cost of living for the nation's poorest families.[82]

LOW EDUCATIONAL ATTAINMENT

The recent affordability crisis is likely to have the greatest long-term impact on low-income children due to the strong relationship between housing and education outcomes. A 2008 report from the Partnership for America's Economic Success finds that children without access to quality and affordable housing are more likely to have poorer health and education outcomes than children in stable housing environments.[83] The study states, "Just one in 10 children from the poorest families have earned college degrees, compared with more than half among children from the top fifth of earners."[84] Specific reasons for lower educational attainment for low-income children include greater frequency of residential moves (resulting in changes of school), likelihood of experiencing homelessness or overcrowding, as well as environmental factors within the home that can affect a child's ability to learn (including exposure to lead and asthma triggers).[85]

HOUSING AND ENERGY BURDEN

Energy burden, measured as total utility cost over gross income, can significantly impact rental burdens (i.e. total gross rent and utility cost over gross income). In 2013, average utility costs for very low-income renters was roughly 16% of gross rent.[86] Although regional climate and fluctuating fuel costs can cause variations in how much utility costs contribute to rent burdens, in 2014, three states with the highest average utility household bills (Alabama, South Carolina, and Mississippi) also had moderate electricity prices.[87] A national study focusing on US metropolitan areas found within each region, regardless of state energy prices, low-income families, low-income multifamily, renters, and African-American households experience an energy burden equal to or greater than the region's median energy burden.[88] An ACEEE study focusing on U.S. metro areas found that overall the median energy burden for all households was 3.5%, whereas the energy burden for low-income households, low-income multifamily, renters, Latino and African-

American households was 7.2%, 5.0%, 4.0%, 4.1% and 5.4%, respectively. This study indicates that energy costs may not play a significant role alone, but when combined with low-incomes, a shortage of affordable housing and inefficient housing, energy costs can exacerbate energy burdens and cause rent burdens to grow among disadvantaged communities. Such evidence is indicative of the growing home energy affordability gap experienced by low-income communities. The Home Energy Affordability Gap— the gap between what low-income households can afford and what they actually pay—was over $41.1 billion in 2015, a 6% increase from 2011.[89] As an example of the variation between states and energy affordability gap, Wyoming households under 200% of the poverty level, the average home energy affordability gap was $569.[90] Comparatively, in Maryland, the average per household gap was $1,489.[91] National fuel assistance for these families available through LIHEAP was only allocated $3.3 million over the same period.[92]

The Home Energy Affordability Gap—the gap between what low-income households can afford and what they actually pay—was over $41.1 billion in 2015, a 6% increase from 2011.

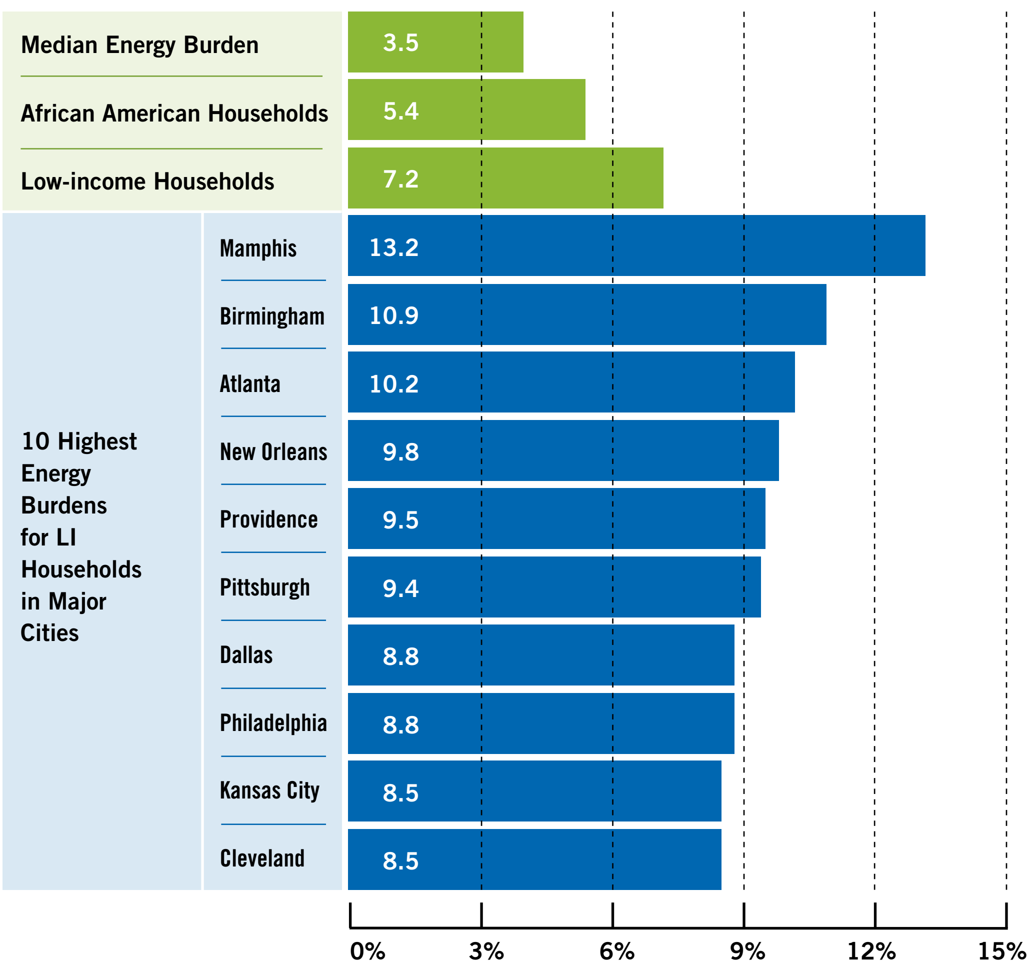
Reliance on filtering also ignores the impact that vacant and dilapidated housing can have on the stability of housing markets, and on low-income households seeking affordable, quality housing. Housing construction regularly exceeds growth rates in metropolitan areas.[93] When metro areas have too many housing units, and higher income households are moving to newer and higher cost housing, areas with older housing and concentrated poverty can experience high vacancy and foreclosure rates, and divestments in occupied housing stock.[94] Neighborhoods with a high concentration of vacant units not for sale, lease or seasonal use (known as chronically vacant) can create dysfunction within a housing market, measured by higher than average foreclosure rates, lowered market value of homes, and longer than average time periods to sell homes. Areas with high chronic vacancy also have increased rates of environmental and health concerns as measured by municipal building and property maintenance code violations, instances of arson, and other indicators of property neglect.[95] As a result, both homeowner and renter households in low-income neighborhoods often occupy market rate housing in areas where basic maintenance has been deferred by the owner because owners are unmotivated to invest in the property due to the depressed value of neighboring units.[96]

Deferred maintenance is one of the primary causes of environmental hazards within housing as well as the energy cost burdens experienced by low-income households.[97] Energy burdens have historically been defined as the percentage of a household's income that is committed to utility costs.[98] Low-income households spend a greater percentage of their income on utility costs, compared to higher income households. Many reasons for higher energy consumption are related to housing quality; low-income households are more likely to occupy units that have structural deficiencies that cause air leakage, older and malfunctioning heating and cooling systems, older and less efficient appliances, and other maintenance issues that increase consumption and reduce thermal control within housing units.[99]

ENERGY INSECURITY

For many households in the U.S. energy burdens and rent burdens combine to drive up housing costs, and result in many social inequalities such as fuel poverty, utility-related debt, and energy insecurity.[100] A recent study defined energy insecurity as the "inability to adequately meet basic household energy needs" and developed a framework for analyzing its effects. According to the study, there are three dimensions of energy insecurity: economic, physical, and behavioral.

Economic energy insecurity refers to the financial burden that low-income households experience as a result of high energy costs.[101] A 2016 study of energy burdens conducted by American Council for an Energy-Efficient Economy (ACEEE) expanded the common definition and knowledge base of energy burdens, analyzing household energy burdens by comparing what certain household groups pay for utilities per square foot in relation to the average household. The study found that among all households sampled in the 48 largest



Ariel Drehobl and Lauren Ross. Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities. American Council for an Energy-Efficient Economy (April 2016) cities in the U.S., the median energy burden was 3.5% for the overall population, while for low-income households the burden was 7.2%, or more than twice as high. African American households of all income levels experienced an energy burden of 5.4%. Energy burdens were highest for low-income households in large cities in the southeast region: Memphis (13.2%), Birmingham (10.9%), Atlanta (10.2%), and New Orleans (9.8%).[102] Energy insecurity can be especially harmful to low-income households as it can cause families to forgo electricity in order to afford rent, food or other necessities.

Furthermore, higher energy burdens for low-income households can threaten energy security, or access to energy utility services. Moderate energy insecurity is often indicated by late payments on utility bills (and the burden of paying fees because of late payments) and the threat of utility shutoff. Severe energy insecurity is associated with households where utilities have been shutoff for one or more days per year, and households that have gone without cooking fuel or heating and cooling services as a result.[103] The 2013 American Housing Survey found more than 2.2 million households experience utility interruption annually.[104] Households that rely on energy safety net programs, such as LIHEAP, are more likely to use other safety net programs to meet basic family health and safety needs. However, there are also households that suffer from the "cliff effect," a term that refers to the situation that many households find themselves in when they are ineligible for safety net programs, yet they are not economically self-sufficient.[105] Energy debts are particularly worrisome in this context as they prevent families from moving out of poor quality housing that contribute to their high energy bills.[106]

Poor quality housing is more likely to use energy inefficient fixtures and appliances, increasing the risk of energy burden among lower-income families.

Physical energy insecurity refers to the "physical deficiencies in the physical infrastructure of the home environment that impact thermal comfort, induce harmful exposures and increase energy costs."[107] Low-income families, whom disproportionately include single-income families, single-parent families, the disabled and the elderly, are forced to settle for poor quality and often older housing in search of affordability. Families' living in cheaper lower quality housing are still at risk for moderate to severe housing burden because of the energy inefficiencies associated with the building.[108] Poor quality housing is more likely to use energy inefficient fixtures and appliances, increasing the risk of energy burden among lower-income families. Children from these households are more likely to have poor education and health outcomes. Households with children that experience energy insecurity are more likely to experience food insecurity, poorer health, and children in energy insecure households have higher hospitalization rates than children from energy secure households.[109]

When families do not have access to affordable housing or energy, they often experience food insecurity simultaneously. A lack of access to food for young children can be detrimental to their physical development and long-term health. A 2002 study of low-income households examined the relationship of housing instability, food insecurity, and health outcomes, finding that "families that experience housing instability and food insecurity, without necessarily experiencing homelessness or hunger, have compromised ability to receive adequate health care for their children."[110] Children without food security are more likely to have no source for wellness care and to go without medical care when needed, and those without housing security are also more likely to experience postponed medical care and utilize emergency departments for medical services.[111] This study demonstrates that when low-income families experience economic insecurity, exhibited in poor housing and related indicators, their children have poorer long-term health and education outcomes.[112] Additionally, healthcare costs could be lowered significantly if housing and food security were more accessible.[113]

Behavioral energy insecurity refers to the strategies and coping mechanisms used by residents to mitigate the impacts of energy in security. These measures include using space heaters, ovens, or stoves to compensate for inadequate thermal comfort and practicing energy conservation strategies for economic instead of environmental reasons, but also present additional health risks to residents.[114]

ECONOMIC SECURITY AND HOUSING STABILITY

The combined burden of housing and energy costs for low-income and moderate-income households threatens family economic security at a significant level. Economic security relates to an individual's current and prospective material well-being. In general households with the most income and education have faced the least insecurity, while households that are less affluent, those with limited education, African Americans, and Hispanics have faced the most economic insecurity.[115] Poor families with children often experience high levels of economic insecurity, increasing the likelihood that families with severe housing cost burdens will experience eviction and homelessness. Cost burdened families are often one financial emergency away from loss of housing.[116] The 2015 Annual Homeless Assessment Report to Congress found that 36% of all homeless people were from families with children, based on point-in-time estimates.[117] A study of households who had received public assistance at least once in their lifetime found that almost 20% had also been homeless at least once.[118]

Individuals in households with high housing cost burdens and associated poor environmental and economic conditions can experience limited or chronic mental health illness. Most research on the correlation between mental illness and low-income households with cost burdens examines the impact of poorly controlled stress, anxiety, depression, and related conditions on household members. For example, mothers experiencing housing disarray and instability are more likely to screen positively for depression and generalized anxiety disorder.[119] Family economic insecurity for a prolonged period and in severe cases contributes to household dysfunction, which not only impacts the mental and physical health of adults in low-income households, but can also negatively impact childhood development, the impacts of which are lifelong. Children experiencing high levels of stress have high levels of cortisol and other stress hormones, which can suppress the body's immune response. This type of stress can disrupt early brain development, and lead to chronic health problems.[120]

Children in households that experience high cost burdens face greater barriers to attending school and performing at grade level than their peers. Because of the high rates of housing mobility for cost burdened households, children from low-income families are more likely to change schools frequently, creating a significant variation in education curricula even in a single school year, which can impact the child's ability to perform at grade level.[121]

The lost economic productivity related to housing instability and unhealthy living conditions created by high cost burdens is also significant. Every individual who does not complete high school, including those impacted by housing instability and inadequacy, costs society an estimated $260,000 in lost earnings, taxes and productivity alone.[122] Lead poisoned children experience significant losses of earning potential.[123] Loss of productivity is not only measured by impact on children with housing related health conditions, but also their caretakers. In particular parents or caregivers of children with asthma have higher rates of missed work days.[124] Low wage workers in low-income households make up about 10.8% of the total workforce. Because low wage workers are employed in industries that offer less job security and benefits than the average person in the workforce, these workers who have children are less likely to maintain consistent employment. Low wage workers are also more likely to have poor health status, which limits their employment options.[125] Family emergencies, such as unplanned moves, illness, or caring for a sick child, can result in loss of income or loss of employment. This increases the financial pressure on low-income households, which raises their risk of experiencing high cost burdens and its related hardships.

ECONOMIC SECURITY FROM REDUCED HOUSING COST BURDEN

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization **Energy Efficiency** **Healthy Homes**	**Increased Household Income Benefits**	**Energy Security** **Lower Incidence of** Reliance on poverty alleviation programs Evictions Vacancies	**DOH-3** Proportion of households experience housing cost burdens **EH-19** Reduce the proportion of occupied housing units that have moderate or severe physical problems	**Economic Stability** Poverty Housing Stability Employment

IMPACT OF POOR QUALITY HOUSING – QUALITY HOUSING CRISIS

Overall housing shortages in local markets reinforce two interrelated negative structural constraints for low- and extremely low-income households: lack of affordable housing and lack of quality housing.[126]

Lack of affordable housing is an ongoing market failure occurring in most urban housing markets in the US, which is partially due to market inefficiencies that prevent low-income occupants from being able to maintain or upgrade the existing housing stock.[127] At the same time the inability to maintain an adequate supply of quality housing is a governance failure which can be corrected through policy change to incentivize the preservation of quality affordable housing. Local governments have set and enforced building code standards in U.S. cities since the late 19th century to limit the hazards associated with poor quality housing. Municipalities have also actively regulated the planning of housing units through effective zoning practices and comprehensive city planning since the early 1900s. A primary purpose of zoning has been to separate residential land uses from others that may cause environmental and health hazards.

As a result of filtering in housing markets, lower income families occupy many of the nearly 30 million American homes with structural damages, elevated lead levels, radon or environmental contaminants that place them at risk for injuries and acute or chronic illnesses.

Generally, American housing markets produce low cost housing through a process called filtering, where existent housing units drop in cost as their relative quality falls, rather than through construction of new, lower cost units.[128] As a result, lower income families occupy many of the nearly 30 million American homes with structural damages, elevated lead levels, radon or environmental contaminants that place them at risk for injuries and acute or chronic illnesses.[129] In fact HUD estimated that of 13.72 million unassisted renters in the United States: 0.22 million lived in severely inadequate housing, 7.23 million lived with severe rent burden, and 0.27 million lived in severely inadequate housing with severe rent burden.[130] Poor quality housing increases the accumulation of negative externalities in low-income neighborhoods affecting many vulnerable populations (i.e. children, elderly, and those in poor health).[131] Thus, constrained by a limited supply of affordable quality housing and the limited resources that families bring to market, low-income households are systematically relegated to poor quality housing, which is a known social determinant of health and economic inequality.[132] Poor quality housing also exposes residents to health and safety hazards that can cause new incidences of disease or exacerbate pre-existing health conditions, in addition to individual costs and negative societal outcome. Hazards

include threats to fire safety, thermal discomfort from extreme temperatures, poor indoor air quality (IAQ), and environmental toxins. The health outcomes most commonly linked to these hazards include fire related injury or death, cardio-vascular disease (CVD), respiratory symptoms, asthma, lung cancer, poor mental health, and skin irritation.[133]

INDOOR AIR QUALITY (IAQ)

As defined by the EPA, indoor air quality refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.[134] By improving indoor air quality occupants of residential buildings can reduce the risk posed to their heath by controlling exposure to indoor pollutants. Common indoor contaminants include: radon, secondhand smoke, mold, irritant and allergenic asthma triggers, combustion by-products (e.g., carbon monoxide, nitrogen dioxide and particles) and volatile and semi-volatile organic compounds (for more information, visit www. epa.gov/iaq). Three primary sources of these contaminants in residential buildings include: gases and particles released from consumer products, toxic building materials (e.g. asbestos and lead) and furnishings; occupant activities (e.g., cooking, hobbies); and infiltration from the outdoors.[135] Inadequate ventilation as well as high temperatures and humidity can often allow these contaminants to build up to unhealthy levels.

Combustion Gases and Ventilation

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization **Source Control:** Removal of all unvented combustion space heaters Repair/replace unvented heat pumps, vented gas heating, or enclosed wood burners **Ventilation:** Increases the volume of indoor to outdoor air exchanged --- **Healthy Homes** Install CO Monitors in homes with Combustion appliances	**Better Indoor Air Quality** Reduced concentration of poly-cyclical aromatic hydrocarbons (PAH), hydrocarbons, aldehydes, carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxides (NOx), and particulate matter (PM) in the home	**Lower Incidence of** CVD related Emergency Room visits Adverse respiratory symptoms COPD CO poisoning hospitalization and death	**EH-22.7** Increase States that monitor diseases or conditions that can be caused by acute exposure to CO poisoning --- **HDS-2** Reduce coronary heart disease deaths --- **RD-1-13** Respiratory Diseases	**Neighborhood & Built Environment** Quality of Housing Environmental Conditions --- **Economic Stability** Poverty Employment

Hazard Identification

Combustion gases released from appliances are a significant source for the release of major indoor air pollutants such as carbon monoxide, particulate matter and nitrogen dioxide.[136] The other principal combustion gases found in the indoor environment of a home are poly-cyclical aromatic hydrocarbons (PAH), hydrocarbons, aldehydes, carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxides (NO_x), and particulate matter (PM) (Canada Mortgage and Housing Corporation, 2013). PAH, CO, SO2, NO_x, and PM in addition to lead and ground-level ozone (O3), are the six common air pollutants. The Clean Air Act requires the EPA to set National Ambient Air Quality Standards (NAAQS) to limit outdoor pollution levels of the criteria pollutants CO, SO2, NO_x, PM, and O3 in accordance with environmentally-based and human health-based criteria. Primary standards for air quality are set to protect human health while secondary standards prevent environmental or property damage.[137]

NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

Pollutant	US Average Range	US Typical Peak	Most Recent NAAQS for Criteria Pollutants (Averaging Time)
O_3 Ozone	0-125 ppb	2000 ppb	75 ppb (8h)
NO_2	0.5-50 ppb	200 ppb	100 ppb (1h) 53 ppb (Annual mean)
NO	0-100 ppb	200 ppb	
SO_2	0.1-50 ppb	150 ppb	75 ppb (1h) 6/22/2010 140 ppb (24h) 30 ppb (Annual mean)
CO	0.1-5 ppm	20 ppm	35 ppm (1h) 9 ppm (8h)
PM_{10}	10-100 $\mu g/m^3$	300 $\mu g/m^3$	150 $\mu g/m^3$ (24h)
$PM_{2.5}$	5-50 $\mu g/m^3$ Mean=(13.4+5.6) $\mu g/m^3$	100 $\mu g/m^3$	12 $\mu g/m^3$ (Annual mean) primary 15 $\mu g/m^3$ (Annual mean) secondary 35 $\mu g/m^3$ (24h)
$PM_{2.5}$ Lead	0.5-5 ng/m^3	150 ng/m^3	0.15 $\mu g/m^3$ (Rolling 3 month average)
PAH	2-50 ng/m^3	200 ng/m^3	NA

Air contaminants are generated primarily through fossil fuel combustion or through secondary chemical reactions producing NO_x and O3 when NO_x and volatile organic compounds interact. The release and accumulation of combustion gases and particles also occurs due to spillage from household appliances, infiltration of outdoor pollution (e.g. pollen, vehicle exhausts, and industrial emissions), or inadequate ventilation. These sources are considered the primary causes of indoor air quality problems within the home environment.[138] A recent U.S. study of indoor air hazards utilizing measured concentration data identified nine priority pollutants, including NO_x and PM2.5, at acute ambient exposure levels that exceed chronic health standards, while activity-based emissions pose potential acute health hazards only for CO, chloroform, NO_x and PM2.5 (Logue, McKone, Sherman, & Singer, 2011). Findings from the "Towards Healthy Air in Dwellings in Europe" (THADE), a European project to improve indoor air quality, similarly determined the major health determinants in dwellings originating from combustion include NO_x, indoor generated particulate matter, CO and CO_2.[139] The consistency of findings across large cohort studies provides ample evidence which indicates combustion-generated gaseous products that are most often of health concern are particulate matter, carbon monoxide and nitrogen dioxide.

Currently there are no enforceable federal primary, health-based, standards for indoor air quality related to residential combustion gas concentrations. Many factors affect IAQ including poor ventilation (lack of outside air), problems controlling temperature, high or low humidity, recent remodeling, and other activities in or near a building that can affect the fresh air coming into the building.[140] Specific activities performed by occupants and building owners contribute to poor IAQ. For example, building use or maintenance may produce contaminants like dust from construction or renovation, mold, cleaning supplies, pesticides, or other airborne chemicals such as VOCs that generate small amounts of chemicals released as a gas over time.[141]

Health Effects

The population health effects of exposure to criteria air pollutants are responsible for regulatory action to protect and improve air quality in the ambient environment. Inhalation is the primary route of exposure by which indoor pollutants from combustion gases and their byproducts are known to affect human health. Exposure to combustion-related pollutants, including both particles and gases, has also demonstrated negative effects associated with cardiovascular and pulmonary diseases. Health effects related to exposure to indoor combustion pollutants may occur after a single exposure or repeated exposures depending on individual susceptibilities, age and preexisting medical conditions.[142] Acute episodic exposures often produce immediate short-term health effects that include irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue.[143] Other health effects may show up either years after exposure has occurred or only after long or repeated periods of exposure. The effects of long term exposure include respiratory diseases, heart disease and cancer, any of which can be severely debilitating or fatal. While pollutants commonly found in indoor air can cause many harmful effects, there is considerable uncertainty about what concentrations or periods of exposure are necessary to produce specific health problems.

Inhalation is the primary route of exposure by which indoor pollutants from combustion gases and their byproducts are known to affect human health.

There is strong evidence of a causal association between air pollutants and negative health effects, excess CO causing carbon monoxide poisoning, short and long-term PM2.5 exposure increasing cardiovascular disease (CVD) morbidity and mortality rates, and radon and ETS increasing lung cancer rates.[144] However, the relationship between exposure to either NO_x or PM2.5 and certain vulnerable populations with respiratory diseases, particularly pediatric asthma and adults with COPD, demonstrates a strong association for pulmonary disease morbidity rates. Over the last decade, the trend in hazard analysis and risk assessment in U.S. research has moved from measuring exposure to single hazards towards analysis of multiple gases and the cumulative effect on human health.[145] The reason is the air pollution in the home environment is a complex mixture of gases, particles and liquids which are continually changing and interacting with each other and natural atmospheric gases.[146] Any health effects attributable to indoor air pollutants depend on a cumulative effect and not just exposure to a single pollutant.[147]

Carbon Monoxide

Residential carbon monoxide levels are strongly associated with combustion appliance use and whether or not occupants allow tobacco smoking indoors.[148] Despite an annual average outdoor CO concentration of 0.12 parts per million (ppm) by volume (ppmv), average ambient concentration can vary from 0.5 ppmv to 15 ppmv depending on gas stove utilization and its condition.[149] CO can arise when fuel-burning appliances are improperly installed, adjusted or maintained, as well as from car exhaust.150 CO can reduce oxygen delivery to the body's organs, causing harm to organ tissues, especially the heart and the brain.[151,152] Acute exposure at extremely high concentration levels can cause loss of consciousness, long-term neurological disabilities, coma, cardio-respiratory failure, and death.[153] In fact, CO poisoning is the leading cause of unintentional poisoning deaths, and causes approximately 15,000 emergency department visits and nearly 450 deaths annually in the United States, 64% occurring in the home.[154,155] Each year more than 400 Americans die due to unintentional carbon monoxide poisoning; more than 20,000 visit the emergency room and more than 4,000 are hospitalized; and fatality is highest among Americans 65 and older.[156]

Each year more than 400 Americans die due to unintentional carbon monoxide poisoning; more than 20,000 visit the emergency room and more than 4,000 are hospitalized; and the highest fatality is among Americans 65 and older.

Low-level CO exposure still leaves persons with ongoing cardiovascular and respiratory disease vulnerable to carboxy-hemoglobin (COHb) formation.[157] Low level exposure to CO decreases the blood's oxygen-carrying capacity and impairs O2 release for use by tissues, with long-term exposure causing "fatigue, dizziness, headache and disorientation."[158,159] This population is also at risk for CO induced myocardial ischemia and angina (chest pain).[160] Due to endogenous CO (naturally occurring CO within the body), minimum risk levels have not been determined.[161] There is convincing evidence that CO exposure causes adverse cardiovascular effects when blood COHb are levels ≥2.4%.[162] Recent epidemiological studies on developmental effects have identified a lowest observed adverse effect level (LOAEL) for human maternal continuous exposure as a COHb blood level of 1.82% or approximately 10ppm.[163] The identified LOAEL for neurological outcomes occur at the human equivalent concentration of 32 ppm (5%) for sensitive populations and 160 ppm (20%) for healthy populations.[164]

Particulate Matter

Research has documented adverse health effects related to exposure to outdoor particulate matter which include stroke, heart disease, lung cancer, and chronic and acute respiratory diseases, including asthma, reduced lung function, and mortality.[165] Exposure to combustion-related indoor pollutants, including both particles and gases, has also demonstrated negative effects associated with cardiovascular and pulmonary diseases.[166] Epidemiological research has demonstrated a causal relation between exposure to PM2.5 and negative outcomes (mortality and hospitalization) related to cardiovascular disease. Studies show greater rates of premature death in people with heart or lung disease, heart issues, and respiratory problems.[167] In a meta-regression study of 26 U.S. communities, researchers found that every 10 $\mu g/m^3$ increase in 2-day averaged PM2.5 concentration increased morbidity rates by 1.89% for CVD, 2.25% for myocardial ischemia, 1.85% for Congestive Heart Failure, 2.74% for diabetes, and 2.07% for respiratory admissions.[168] Short term exposure to PM2.5 can trigger CVD-related mortality and non-fatal events, especially in susceptible individuals.[169,170] Findings in most studies report long-term exposure increases cardiovascular mortality risk compared to short-term acute exposure.[171] Both monotonic short- and long-term PM2.5 exposures are associated with increased CV mortality risk, even when concentrations are below the NAAQS standard of 15 μg/m^3 average annual levels.[172,173] The lack of a discernible "safe" threshold provides evidence that further suggests any reduction in particulate exposure will have health benefits to the general population.

Outdoor particulate matter with a diameter measuring less than 2.5 micrograms (PM2.5) is another common source of residential indoor levels of PM2.5 exposure. Through the process of infiltration, PM can be introduced and circulated through natural ventilation and by HVAC systems, exposing occupants to a serious health hazard. Multiple studies have documented the extent to which human exposure to outdoor PM occurs indoors, including at home.[174] A 2011 review of 77 studies covering more than 4,000 homes found that the average ratio of indoor PM to outdoor PM—where the indoor PM includes contributions from both indoor and outdoor sources—is approximately 1.0 for PM2.5 and approximately 0.8 for PM10 and UFPs.[175] Outdoor PM enters buildings not only by infiltrating through cracks and gaps in the building envelope but also through natural ventilation and mechanical ventilation. Important indoor sources of PM include combustion, candles, and cooking. A study carried out to determine the infiltration factor (proportion of outdoor PM that penetrates indoors and remains suspended) of PM in residential homes found that mean infiltration of the homes surveyed was significant.[176] Other sources of indoor PM2.5 include combustion, candles, cooking, vacuum cleaners, printers, radiators, flat irons, and cigarettes.[177] These sources are characterized by emissions rates that range from 6.0x109 particles per minute to 1.1-3.4x1012 particles per minute.[178] While the initial exposure is damaging, the subsequent exposures from re-suspension of accumulated PM also present a risk. There are several causes of re-suspension such as aerodynamic lift and drag, surface vibration forces, electrostatic forces, and human induced particle re-suspension from activities like walking, crawling, and turning over in bed. Walking emits 1-10 milligrams per minute and over a lifetime, a single person can suspend up to 100 kilograms of dust.

Outdoor PM enters buildings not only by infiltrating through cracks and gaps in the building envelope but also through natural ventilation and mechanical ventilation.

NO_x

The annual mean outdoor ambient NO_x rarely exceeds 0.2ppm and generally remains below NAAQS regulatory standard for NO_2 of 0.053 ppm (annual average). Yet inside homes, 1-hour NO_2 peaks can range between 0.4 and 1.5 ppm.[179] Gas cooking, followed by poor ventilation and outdoor ambient NO_2 are the most important predictors of indoor NO_2 concentrations.[180] Interpreting NO_2 exposure evidence is complicated because the nitrogen oxides that generate NO_2 are strongly correlated with other unmeasured pollutants emitted from motor vehicles.[181] Health effects could be attributed to NO_2 exposure or its reaction products including ozone (O_3) and secondary particles.[182]

Evidence from epidemiological studies indicates that long-term NO_2 exposure may decrease lung function and increase the risk of respiratory symptoms. A critical review found limited evidence of adverse effects for short-term exposure to a 1-hour mean value $< 200\ \mu g/m^3$, yet the review found moderate evidence that short-term exposure below a 24-hour mean value of 50µg NO_2/m^3 increases hospital admissions and mortality.[183] Similarly, moderate evidence provided by generally consistent findings in five well-conducted cohort and case-control studies showed that long-term exposure to an annual mean below 40µg NO_2/m^3 was associated with adverse health effects (respiratory symptoms/diseases, hospital admissions, mortality, and otitis media).

A study on environmental tobacco smoke (ETS) and NO_2 reported indoor NO_2 median level at 29.8 ppb compared with the U.S. national outdoor median of 18 ppb.[184] Interestingly the study reported no effect of ETS exposure on symptoms or use of health care services, while higher levels of indoor NO_2 were associated with increased asthma symptoms in non-atopic children and decreased peak flows.[185] Secondary analysis of a randomized community trial examined the impact of NO_2 on the respiratory health of asthmatic children reported higher indoor NO_2 levels were associated with greater daily self-reported lower and upper respiratory tract symptoms (mean ratio 1.14 and 1.03 respectively) as well as a decrease in morning and evening forced expiratory volume in 1-second readings. While outdoor NO_2 was not associated with respiratory tract symptoms, asthma symptoms, medication use or lung function measurements.[186]

A critical review of 50 short-term exposures experimental studies that focused on clinical studies with healthy and at risk subjects found that healthy subjects exposed to NO_2 below 1 ppm do not show pulmonary inflammation. The same review found no consistent evidence that NO_2 concentrations below 2 ppm increased susceptibility to viral infection. For asthmatics and those individuals with chronic obstructive pulmonary disease (COPD), the NO_2-induced lung inflammation is not expected below 0.6 ppm, although one research group reported enhancement of pro-inflammatory processes at 0.26 ppm.[187] Studies suggest that asthmatic individuals were not affected by NO_2 up to about 0.6 ppm, although some sensitive subsets may respond to levels as low as 0.2 ppm. Extra-pulmonary effects (i.e. changes in blood chemistry) generally required NO_2 concentrations above 1-2 ppm.[188] Thus, the authors concluded that the "available human clinical results do not establish a mechanistic pathway between short-term NO_2 exposures and adverse health impacts at levels typical of the present-day ambient environment (i.e., < 0.2 ppm)".[189]

Remediation

IAQ can be improved in buildings by integrating IAQ best practices that target multiple indoor air contaminants using strategies consistent with EPA guidelines. The following section reviews several strategies proven to improve combustion pollutants and their associate health effect. Interventions proven effective at preventing CO poisoning include installing CO monitors, maintenance and repair of combustion appliances, filter replacement and education on proper use of ventilation both exhaust and supply to improve indoor air quality.

IAQ can be improved in buildings by integrating IAQ best practices that target multiple indoor air contaminants using strategies consistent with EPA guidelines.

Source Control

Source control is the most cost-efficient approach, achieved through elimination of inadequate and unhealthy heating sources, regular maintenance, and repair or replacement of household combustion appliances (i.e. wood, coal or biomass stoves and open flame cookers). The WAP procedures require that unvented combustion space heaters are removed during renovations, whereas solid fuel heaters should be repaired if they pose a health and safety risk.[190] A New Zealand intervention, where inadequate heaters were replaced in homes using unvented gas heaters, had more than three times the NO_2 level in living rooms than homes without unvented gas heaters, whereas homes using gas stove-tops had significantly elevated living room NO_2 levels. Homes with heat pumps, vented gas heating, or enclosed wood burners had significantly lower levels of NO_2 in living areas and bedrooms, while the intervention was associated with a two-thirds (67%) reduction in NO_2 levels in living rooms.[191] CO monitoring devices installed in homes have been shown to reduce ED visits, hospitalizations and deaths. Households who possessed CO monitors prior to their weatherization were calculated to be less likely to have visited the ED or been hospitalized for CO poisoning.[192] The findings from the Retrospective evaluation of the 2008 WAP reported that CO monitors alone could prevent roughly 65% of CO poisoning deaths.[193]

Ventilation

Ventilation is another cost-effective means to improve air quality as it increases the volume of indoor air exchanged with outdoor supply to dilute or remove contaminants. If homes indicate there is a problem with combustion gas, ventilation is the measure typically utilized by WAP.[194] In a study that examined the impacts of residential ventilation protocols used in low-income housing weatherization, researchers compared the IAQ in pre- and post-weatherization homes with either ASHRAE 62-1989 or ASHRAE 62.2-2010 compliant ventilation systems.[195] Overall CO_2 levels were 13% lower post weatherization homes. When comparing the two different ventilation protocols, homes that installed ASHRAE 62.2-2010 compliant ventilation systems saw statistically significant drop in CO_2 level, whereas homes that installed ASHRAE 62 -1989 systems did not.[196] In both groups, there were fewer incidences of headaches, eczema and skin allergies among children. Adults also saw improvements in psychological distress.[197]

A study scrutinized the day-to-day relationships between PM2.5 and cardiovascular/respiratory hospitalizations, and between PM10 (<10µm diameter) and mortality in the context of differing prevalence of AC systems. The study found that a 20% increase in AC system prevalence was correlated to a 43% decrease of PM-related cardiovascular hospitalizations. This study was conducted on people aged 65 and older, and did not control for socioeconomic factors between communities or within them. Despite these limitations, the study provides further evidence of the benefits of increased AC usage, particularly as central AC incidence was judged to explain 17% of intra-community variation in cardiovascular hospitalizations.[198]

Indoor environmental interventions are also prone to complex tradeoffs among pollutants, as interventions that influence ventilation can have opposing effects on indoor and outdoor sources.[199] For example, improved venting of gas stoves or increased ventilation in general will reduce indoor sources of NO_2 concentrations; however, increasing general ventilation can increase indoor NO_2 concentrations from outdoor sources, especially in urban settings with high traffic.[200]

Air Cleaners or Filtration

Overall effectiveness of air cleaners depends on how well the system collects pollutants from indoor air (percentage efficiency rate) and the volume of air (cubic feet per minute). Most residential systems are not designed to remove gaseous pollutants but are highly effective at particle removal. Studies suggest indoor concentrations of ambient particles and the associated health risks can be reduced by using mechanical ventilation systems with supply air filtering in buildings.[201]

Health Savings

Based on CO risk estimates for 2008 WAP recipients, ORNL calculated that CO poisoning could have resulted in 38 emergency department (ED) visits, 6 hospitalizations and 0.32 deaths in a given year, if recipients had not received WAP services. Assuming that all WAP participants properly maintained their weatherization repairs, CO emitting devices and CO monitors, it is estimated that all of the ED visits, hospitalizations, and deaths could be prevented and $2,525,000 in associated costs avoided.[202]

To investigate the indoor exposure to PM2.5 under different residential air cleaners, researchers combined the CONTAM indoor air quality simulation model with seven residential building templates, representative of U.S. single family building characteristics.[203] Comparing all home types and locations demonstrated the following results: median daily average in homes with high-efficiency (HE) air filtration was 1.5 $\mu g/m^3$, whereas the median daily average in homes with conventional filtration was 5.3 $\mu g/m^3$, and 8.4 $\mu g/m^3$ in homes with natural ventilation.[204] Assuming that a 1 $\mu g/m^3$ change in ambient PM2.5 would correspond with an approximate 0.6 $\mu g/m^3$ change in mean personal PM2.5, findings show the decrease in annual mortality risk associated with conversion from conventional to HE air filtration is 3.7%, 4.2% from natural ventilation to conventional filtration, and 7.8% from natural ventilation to HE air filtration.[205] The findings led the authors to conclude that installing whole residence in-duct air cleaning at the population scale may be comparable or greater to regional health benefits attributed to emission control technologies.

The impact on health and economic savings from residential NO_x reductions is not clear. There are limited studies and the exposure tradeoffs from the increased ventilation make it difficult to study.

Volatile Organic Compounds

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization Removal of VOCs emitting materials and products **Healthy Homes** Education on how to reduce VOC exposure	**Better Indoor Air Quality** Lower levels of ambient VOCs in the home	**Lower Incidence of** Skin and eye irratation Asthma symptoms Pulmonary damage Amyotrophic lateral sclerosis (ALS), VOC related headaches, memory loss, sleep disorders, dizziness, and neurological diseases with aging.	**EH-10** Reduce the amount of toxic pollutants released into the environment	**Neighborhood & Built Environment** Quality of housing Environmental conditions **Education** School attendance **Health and Health Care** Access to primary care and health literacy

Hazard Identification

Volatile organic compounds (VOCs), are carbon-based chemicals present in many common, household items that evaporate at room temperature, causing them to be emitted as gases into the air. The EPA has found concentrations of VOCs to be two-to-five times higher indoors than outdoors.[206] Some VOCs are invisible, tasteless, or odorless, making many people ignorant of their existence and potential danger. Although some VOCs have a distinct smell, people are unaware that inhaling the smell can be dangerous. Higher VOC concentrations are shown to correlate with adverse health effects, and to be toxic.[207]

Formaldehyde, a widely known VOC, commonly comes from building materials such as plywood, fiberboard, and particleboard. Other VOCs include acetaldehyde, benzene, toluene, vinyl cyclohexane, butyl ether, isopentane, isopropanol, butoxy ethanol, hexanal, pentanal, naphthalene, styrene, and phenol.[208] The sum of all of the VOCs found in an area is called total volatile organic compounds (TVOCs), and is measured in $\mu g/m^3$.

Common household VOC emitting products are adhesives, sealants, carpet, and cleaning chemicals. Because so many VOCs exist and are typically emitted at different rates over a long period of time, it is difficult to measure them and create regulations, however, there are regulations for formaldehyde. In the United States, the legal occupational limit for formaldehyde exposure that lasts less than fifteen minutes is 2 ppm; for exposure that lasts more than fifteen minutes, it is 0.75ppm. In contrast, the National Institute for Occupational Safety and Health suggests that the short-term and long-term exposures be limited to only 0.016 ppm and 0.1 ppm, respectively.[209]

Some studies have found that children are more vulnerable than adults to the negative health effects of formaldehyde and VOC exposure, particularly asthma. Because VOCs are difficult to measure, studies have had inconsistent findings, with some showing positive correlation between exposure and health problems and others showing no correlation.[210]

Sick Building Syndrome (SBS) is one documented effect of VOCs. SBS is a medical condition where people in a building suffer from illness or feeling unwell for no apparent reason. The symptoms of SBS increase the more time spent in the building. Interior decoration materials, rugs, furnishings, paint, and pressed wood items are major sources of VOCs, especially inner buildings.[211] One of the more widely researched long-term effects of VOC exposure is cancer. Benzene, toluene, aromatic hydrocarbons, chloroform, and styrene are the major VOCs categorized as carcinogenic chemicals found in indoor air.[212]

Health Effects

The majority of research regarding the health effects of VOCs has been concentrated on formaldehyde, as others are more difficult to measure.[213] Most tissues in the body are able to break down formaldehyde into its non-toxic form and safely excrete it. Higher concentrations of formaldehyde are toxic because they react with body tissues, namely mucous tissues lining the respiratory tract and eyes. These moist tissues contain a thin epithelial layer that is easily irritated by chemicals.[214]

Health effects of formaldehyde depend on the length of time that a person is exposed and a person's age. Evidence shows formaldehyde concentration levels less or equal to 0.3ppm produce no irritation, however this "safe" threshold lowers with age and length of exposure. Acute exposure generally leads to nose, throat, eyes, or skin irritation. More serious exposure can lead to conjunctivitis as well as nose and throat diseases. It also can increase a person's susceptibility to laryngospasm and pulmonary edema. Acute ingestion of formaldehyde liquids may lead to throat and gastrointestinal tract irritation, as well as abdominal distress or acute renal failure. Dermal allergies to formaldehyde are common for those who are occupationally exposed to it.[217] Inhaled formaldehyde can lead to allergic asthma, especially in children.[218]

Long-term exposure to formaldehyde and other VOCs have many of the same effects as acute exposure, as well as inflammatory and hyper-plastic changes of the nasal mucous, pharyngeal congestion, chronic rhinitis, loss of ear functioning, eye disorders, heartburn, tremor, and lethargy. Formaldehyde can also alter mRNA patterns associated with gene expression, leading to the onset of a variety of serious diseases. Effects of formaldehyde on the brain include headaches, memory loss, sleep disorders, dizziness, and neurological diseases with aging. The American Cancer Society found that people who occupationally work with formaldehyde had a 34% higher rate of amyotrophic lateral sclerosis (a fatal neurodegenerative disease associated with the 2015 Ice Bucket Challenge online campaign) than those who were not exposed.[219]

Health effects related to formaldehyde exposure depend on the length of time that a person is exposed and a person's age.

Long-term residential exposure to VOCs can result in pulmonary damage, poor pulmonary ventilation, and cause diseases like rhinitis and epithelial dysplasia. Over time, formaldehyde exposure can lead to decreased white blood cells, platelets, and hemoglobin counts.[220] The International Agency for Research on Cancer has classified formaldehyde as a carcinogen that can cause nasopharyngeal cancer under conditions with unusually high concentrations, like certain occupations, or prolonged exposure. Some scientists have loosely tied formaldehyde to leukemia.[221]

Remediation

Source Control

When formaldehyde or other VOCs pose a risk to weatherization workers, WAP recommends that the source is removed.[222] If the source cannot be removed,[223] VOC education on the safety and proper disposal of household contaminants is provided. In order to reduce VOC exposure, the EPA suggests following all manufacturers' directions for household products, maintaining good ventilation and an ample supply of fresh air, disposing of any unused containers of paints or similar materials, removing sources of VOCs whenever possible, using a sealant over any VOC emitting surfaces that cannot be removed, avoiding inhaling fumes from newly painted areas, and employing integrated pest management techniques to reduce the need for pesticides. Always let new furniture or carpets "air out" before exposing oneself to them.[224]

Ventilation

The EPA suggests that, in order to reduce formaldehyde exposure, one should use air conditioning and dehumidifiers to sustain a moderate temperature and low humidity, and increase ventilation.[225] Ventilation systems installed during weatherization, such as those compliant with ASHRAE 62 and ASHRAE 62.2, have been shown to reduce the mean ambient indoor formaldehyde levels by 19% post weatherization.[226] Ventilation can also be effective against VOCs. However, research found that ventilation systems that met the newer ASHRAE 62.2 standard significantly lower TVOCs by 30% post weatherization, whereas ventilations system under the ASHRAE 62 standard had no effect.[227]

Health Savings

Because of the lack of research on the health effects of VOCs, literature is limited on the health savings produced by lowering semi-VOC and VOC concentrations indoors. Epidemiologists are conducting research that indicates VOCs play a more significant role as asthma triggers than previously thought, and that exposure to VOCs typically occurs in the home.[228] Reducing exposure to VOC in the home would reduce the cost associated with asthma care and other respiratory diseases.

Radon

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization Cover exposed ground in the homes (i.e. basements) with a vapor barrier Make HVAC units ASHRAE compliant Install radon mitigation system	**Better Indoor Air Quality** Drop in radon levels in all levels of the home	**Lower Incidence of** Radon attributable lung cancer cases	**EH-14** Increase the proportion of homes with an operating radon mitigation system for persons living in homes at risk for radon exposure **C-2** Reduce the lung cancer death rate	**Neighborhood & Built Environment** Quality of housing Environmental conditions

Hazard Identification

Unlike many other household contaminants, radon (Rn) is naturally-occurring, odorless, colorless, radioactive gas found in certain geological formations. Radon progenies, the result of decaying uranium and radium, emanates from the ground through existing pores but also during major constructions. Radon progenies enter buildings themselves via water and gas piping or through compromised building foundations.[229] High home radon concentrations are associated with several forms of cancer and respiratory disorders. Radon exposure primarily occurs when radiated radon can be absorbed through the skin and dissolves in fatty tissue, where it can gain access to numerous organs through systemic circulation. Alternatively, radon can attach itself to particulate matter (PM) and aerosols, and is subsequently inhaled.[230]

Risk for radon exposure varies widely according to geological location. The Environmental Protection Agency (EPA) assigned a radon potential score to different U.S. location based on geological and soil surveys but exposure risk is complicated by house type and quality.[231] Drilling into the soil can release more radon, therefore buildings with basements have the greatest exposure potential especially if basements have structural cracks and crevices.[232]

Health Effects

Cancer

Radon is the second biggest risk factor for lung cancer after tobacco use or exposure.[233] Several studies, conducted on miners around the globe, have found links between radon exposure and later lung cancer genesis, with similar outcomes seen after exposure to indoor residential radon exposure.[234] In 1982, the Cancer Prevention Study-II (CPS-II) recruited over 1.2 million volunteers for a prospective study. *Turner et al.* analyzed the cohort and residential radon levels through 1988.[235] After controlling for demographic characteristic, Turner et al. observed a 1.15 (95% CI, 1.01–1.31) hazard risk (HR) for lung cancer mortality per 100 Bq/m^3 increase in radon (pp.442).[236] For subjects exposed to radon above the EPA guidelines (≥148 Bq/m3), risk for lung cancer was 34% greater compared to those under the guidelines.[237]

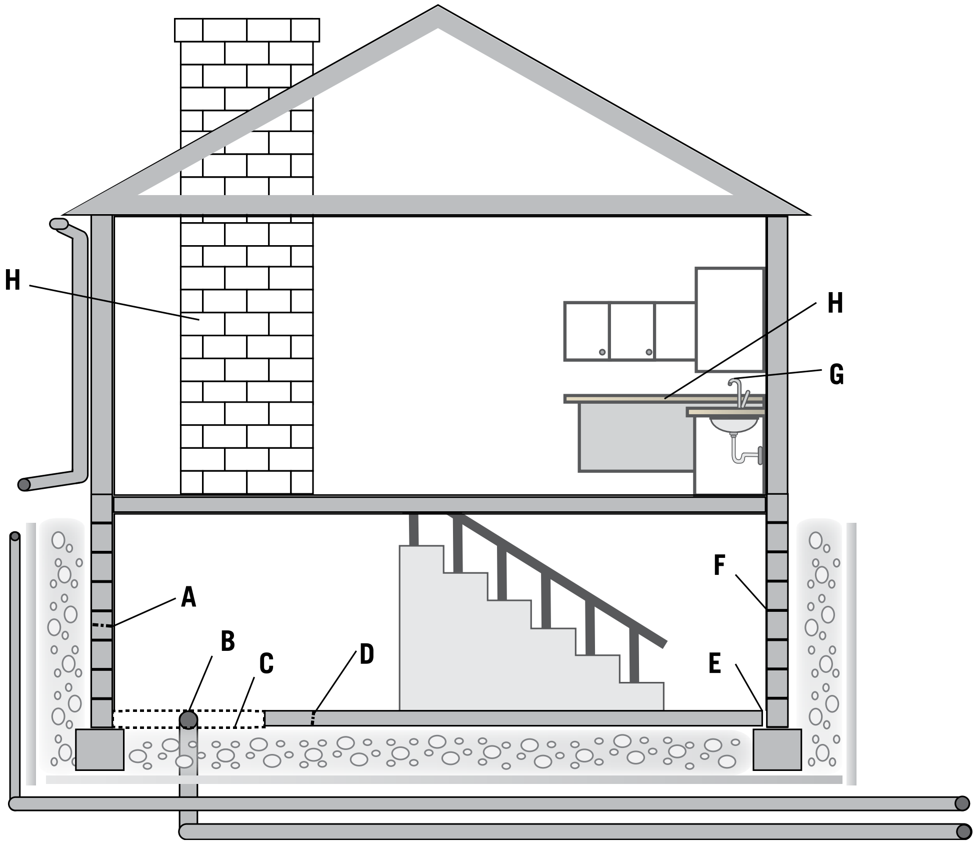
Radon is the second biggest risk factor for lung cancer after tobacco use or exposure.

Another large cohort study showed that even low level radon exposure is associated with brain tumors by finding significant associations and exposure-response patterns between long-term residential radon exposure in a general population and risk of primary brain tumors.[238] Between 1993 and 1997 Danish researchers recruited and tracked 51,674 individuals through 2009. Researchers also traced their residential history from 1971 and calculated their potential radon exposure.[239] An increase in Incidence Rate Ratio (IRR) was also observed at every quartile with the largest being observed as the 4th quartile.[240]

Respiratory Problems

With radon linked with lung cancer, it is unsurprising that studies have linked radon exposure to other pulmonary and respiratory disorders. Another study, utilizing the CPS-II cohort, analyzed and tracked over 800,000 subjects from 1982 through 2006. Historical residential radon exposure (based on ZIP codes) was traced and incidence of non-malignant respiratory disease was recorded. After controlling for demographic characteristics, a Cox proportional hazard regression revealed a significant positive

RADON–PRIMARY ENTRY POINTS IN HOME



A: Pores and cracks in concrete blocks

B: Drain pipes (if cracked or damaged)

C: Exposed soil

D: cracks in concrete slabs

E: Floor and wall joints

F: Mortar joints

G: Water (from some walls)

H: Building materials (such as granite or other rock)

Source: Washington District of Columbia. "How Radon Enters Your House." Department of Energy and the Environment. https://doee.dc.gov/radon (2016)

association between radon and all non-malignant respiratory disease mortality (HR 1.08, 95% CI 1.03–1.13) per 100 Bq/m-3.[241] The analysis also found a significant correlation between chronic obstructive pulmonary disease (COPD), which includes chronic bronchitis and emphysema, and radon exposure (HR 1.13, 95% CI 1.05–1.21).[242]

Remediation

Radon enters the home from ground through structurally weak points. Figure 2 illustrates the major radon entry points. Many of the same weatherization interventions used to prevent homes against dampness and water infiltration in flood prone areas can be used to fortify buildings against radon. During WAP retrofits exposed dirt is covered with a vapor barrier. In units situated in areas that have been identified to be at increased risk for radon or when assessments indicate there is radon present, precautions are taken to reduce the weatherization measures' likeliness of exacerbating the radon issue.[243] WAP technical guidance requires contractors to ensure that any weatherization measures do not increase the concentration or risk of exposure for radon for occupants and work crews.[244]

RADON RISK EVALUATION CHART FOR SMOKERS AND NONSMOKERS (MODIFIED FROM EPA 2009)

SMOKERS

Radon level	If 1,000 people who smoked were exposed to this level over a lifetime...*	What to do: Stop Smoking and...
20 pCi/L	About 260 persons could get lung cancer	Fix your home
10 pCi/L	About 150 persons could get lung cancer	Fix your home
8 pCi/L	About 120 persons could get lung cancer	Fix your home
4 pCi/L	About 62 persons could get lung cancer	Fix your home
2 pCi/L	About 32 persons could get lung cancer	Consider fixing home between 2 and 4 pCi/L
1.3 pCi/L	About 20 persons could get lung cancer	(Reducing radon levels below 2 pCi/L is difficult)
0.4 pCi/L	About 3 persons could get lung cancer	(Reducing radon levels below 2 pCi/L is difficult)
0 pCi/L	Calculated absence of risk	Impossible to accomplish. The lowest feasible concentration equals outside background.

* Lifetime risk of lung cancer deaths from EPA Assessment of Risks from Radon in Homes (EPA 402-R-03-003).

NON SMOKERS

Radon level	If 1,000 people who did not smoke were exposed to this level over a lifetime...**	What to do: Stop Smoking and...
20 pCi/L	About 36 persons could get lung cancer	Fix your home
10 pCi/L	About 18 persons could get lung cancer	Fix your home
8 pCi/L	About 15 persons could get lung cancer	Fix your home
4 pCi/L	About 7 persons could get lung cancer	Fix your home
2 pCi/L	About 4 persons could get lung cancer	Consider fixing home between 2 and 4 pCi/L
1.3 pCi/L	About 2 persons could get lung cancer	(Reducing radon levels below 2 pCi/L is difficult)
0.4 pCi/L	On average, fewer than 1 person (0.7) could get lung cancer	(Reducing radon levels below 2 pCi/L is difficult)
0 pCi/L	Calculated absence of risk	Impossible to accomplish. The lowest feasible concentration equals outside background.

** Lifetime risk of lung cancer deaths from EPA Assessment of Risks from Radon in Homes (EPA 402-R-03-003).

Source: US EPA. " A Citizen's Guide to Radon: The guide to protecting yourself and your family from Radon" US Environmental Protection Agency EPA 402/K-12/002 (2016).

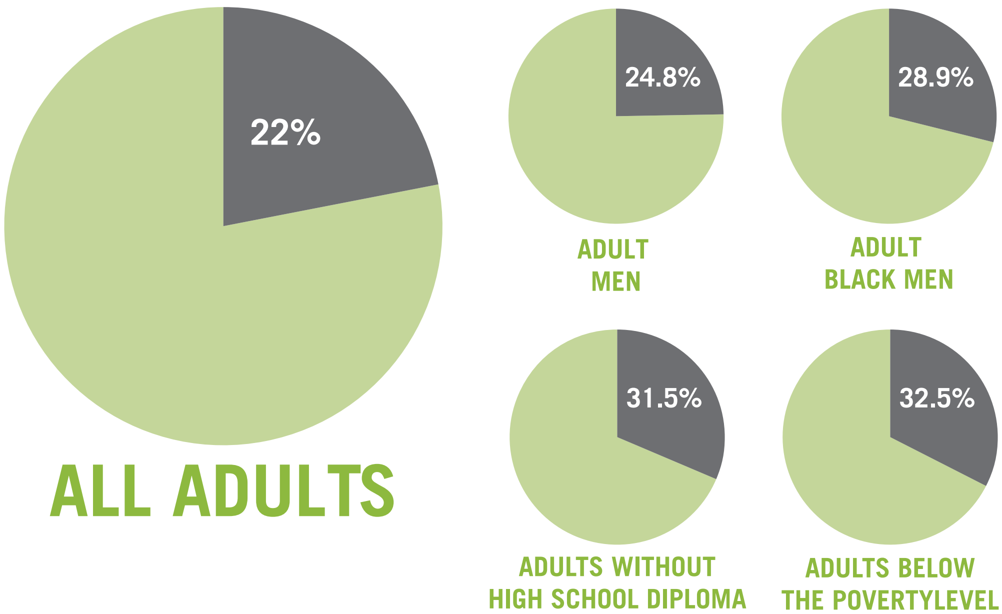
Ongoing ventilation is a promising method to reduce radon concentration in the home. In a study that compared radon levels before and after the installation of ASHRAE 62.2 compliant ventilation systems during weatherization, results showed a statistically significant 32% drop in radon levels on the first-floor post-weatherization.[245] In another weatherization study, radon levels in 18 WAP households with ASHRAE compliant ventilation systems were monitored. The 18 households had been previous assessed to have elevated indoor radon levels. After 1 household was dropped from the study, analysis showed that indoor radon levels declined 12% on average while the ventilation was running 12%.[246]

Radon progenies can also attach to PM and other VOCs, therefore the methods used to remove PM and VOCs from homes could be equally effective at reducing radon concentrations. Additionally, installing a radon sump under the foundation can be effective at removing radon from residential buildings.[247]

Health Savings

In the US, the EPA estimated that 21,000 lung cancer deaths annually are attributable to radon.[248] Thus reducing radon levels in the home could dramatically reduce lung cancer mortality in the US. A Canadian study estimated that radon exposure is responsible for roughly 13.6% of lung cancer deaths in Ontario.[249] A United Kingdom (UK) study performed a cost effectiveness study on England's national radon prevention/intervention scheme. At the time of the study, the UK action level for existing homes was 200 Bq/m3 (note that the EPA level of concern is >148 Bq/m3).[250] New homes in high radon areas were required to install radon prevention material.[251]

PREVALENCE OF SMOKING AMONG U.S. ADULTS



Source: U.S. Department of Health and Human Services. The Health Consequences of Smoking–50 Years of Progress. A Report of the Surgeon General, Atlanta GA. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office of Smoking and Health, 2014.

The study revealed that after basic radon prevention for existing homes, cumulative lifetime risk of death from lung cancer fell from 7.82% to 6.19%, which is equivalent to 39 averted deaths per 1000 average sized households.[252]

A Swedish study extrapolated from past radon-related lung cancer mortality and current indoor radon exposure to estimate future radon lung cancer mortality. Based on 2010 exposure, the study estimated that radon would be responsible for 473 lung cancer deaths. The study further calculated that if radon levels >100 Bq/m^3 are lowered to 100 Bq/m^3, 183 cases would be prevented.[253] In light of similar research findings, the WHO recommended that countries establish a national average concentration reference level of 100 Bq/m^3, but if that reference level is not feasible, reference levels should not exceed 300 Bq/m^3.[254]

There are fewer studies exploring the effect of radon reduction on brain cancer and respiratory disorder incidence, however, it is reasonable to infer that reducing indoor radon would reduce the mortality rate of both. Furthermore, reducing indoor radon alleviates chronic respiratory disorders symptoms, along with reducing the number of associated hospitalization and both school and work absenteeism.

Environmental Tobacco Smoke

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization **Insulation:** Improve home insulation **Ventilation:** Increases the volume of indoor to outdoor air exchanged **Healthy Homes** Resident education on smoking cessation and Environmental Tobacco Smoke reduction strategies Implementation of smoke free policies	**Better Indoor Air Quality** Reduced tobacco use indoors Reduced second hand smoke exposure	**Lower Incidence of** Respiratory illness, including asthma, COPD, and chronic bronchitis Cardiovascular disease Cancer Pre-natal illness and Sudden Infant Death	**Tobacco Use- 1 - 7, 11 & 14** Reduce tobacco use by adults Reduce tobacco use by adolescents Reduce the initiation of tobacco use among children, adolescents, and young adults Increase smoking cessation attempts and success Reduce the proportion of nonsmokers exposed to secondhand smoke Increase the proportion of smoke free homes	**Neighborhood & Built Environment** **Environment:** Quality of Housing Environmental Conditions **Health & Health Care:** Access to primary care and literacy.

Hazard Identification

Environmental Tobacco Smoke (ETS), also known as second hand smoke, is the mixture of gases and particulate matter emitted from burning cigarettes and exhaled by smokers.[255] While ETS contains over 60 toxic compounds, the International Agency for Research on Cancer (IARC) has only deemed 30 to have sufficient evidence of carcinogenicity in human and animals.[256] Despite tobacco use declining significantly from mid-1960s levels, there is still tobacco use disparities between different demographic groups.[257] The prevalence of cigarette smoking among United States adults is 22%, with higher rates observed among men compared to women (24.8% verses 19.3 %). Black men, those without a high-school diploma, and people below the poverty level at rates of 28.9%, 31.5% and 32.5%, respectively, all have cigarette smoking prevalence's above the national average.[258]

The relationship between poverty and smoking rates indicates that residents living in low-income communities are more likely to be exposed to environmental tobacco smoke (ETS).

The relationship between poverty and smoking rates indicates that residents living in low-income communities are more likely to be exposed to ETS. This relationship was one of many motivating factors behind HUD's decision requiring Public Housing Authorities (PHA's) implement smoke-free policies inside all Public Housing except for Section 8 Housing.[259] Despite this move, many low-income residents are still at risk of exposure to ETS. Fabrics and materials worn by smokers or near smokers (e.g. clothing, bedding, curtains, and carpet) can absorb ETS and degas later.[260] Additionally, ETS can seep in from outside. Among children whose homes had no smoking indoors, those living in multifamily housing had 45% higher cotinine levels (indicating ETS exposure) than children living in single family home.[261] Thus, ETS exposure is still likely, even if smokers do not smoke in their indoors. Building ventilation, whether done naturally or with mechanized systems, can remove ETS from the indoor environments. However, some ventilation systems do not remove all the components of ETS from the building and, in some case, facilitate ETS exposure by distributing the toxic chemicals throughout the home.[262]

Health Effects

Since 1964, over 2 million nonsmokers have died from ETS related diseases and health issues.[263] The health effect associated with ETS exposure mirror the health effects experienced by smokers. The following section will highlight the largest contributors to the ETS-related deaths among nonsmokers.

Respiratory Effects

ETS exposure can have harmful effects on lung function, especially if the inflicted person has existing respiratory health issues. Results from 3 studies on ETS exposure indicated that acute respiratory symptoms occur with slightly increased frequency among adults with mild to moderate asthma compared to the healthy control group.[264] There is limited but compelling evidence that suggests ETS exposure is a risk factor for adult asthma diagnoses. One such study that followed 3,577 nonsmokers for 10 years, during which 78 participants developed asthma. After controlling for demographic and environmental characteristic, nonsmokers exposed to workplace ETS would be 1.5 times more likely to develop asthma compared to unexposed nonsmokers (Relative Risk (RR)= 1.5 [95% CI, 1.2-1.8]).[265] Similarly to asthma, several etiologic studies indicate ETS exposure can lead to COPD. A study on 4,197 Swiss adults (aged 18-60) investigated the impact of self-reported exposure to ETS at home and at work in the previous 12 months, found that ETS exposure was significantly associated with reports of chronic bronchitis (OR = 1.7 [95% CI, 1.3-2.2)[266]

While the studies on adults are more suggestive of a causal relationship between ETS and respiratory health problems, the impact of ETS on children is stronger. Out of 41 studies identified by the US. Surgeon General on childhood asthma prevalence and parental smoking, 38 had odds ratios (OR) greater than 1. Additionally, a meta-analysis of studies on the incidence of asthma and wheezing showed the impact of maternal smoking was most significant when it occurs during the first 7 years of life.[268] Although there is only suggestive (but not conclusive) evidence of a causal relationship between ETS exposure from parental smoking and the onset of wheeze and asthma in early childhood, The Institute of Medicine (IOM) has concluded there was sufficient evidence "of a causal relationship between chronic ETS exposure and exacerbation of asthma in preschool-aged children."[269]

Perinatal Effects

Several studies have revealed ETS exposure during the perinatal stage can cause adverse health effects unrelated to respiratory issues. Sudden Infant Death (SID), the sudden and unexplained death of an infant within their first 12 months, is one such health effect strongly associated with ETS exposure. In 1997, researchers working with the California Environmental Protection Agency (CAL/EPA) examined 39 studies on the relationship between ETS exposure and SID. According to their analyses, postnatal maternal smoking produces an adjusted OR of 1.94 (95% CI, 1.55-2.43), indicating a causal relationship between early ETS exposure and SID.[270,271] Nine studies published after 1997 investigated the same relationship but controlled for confounds (e.g. birth weight, prenatal smoking, etc.). All 9 studies found a significant associated between postnatal maternal smoking and SID.[272]

Low birth weight can be the result from premature birth and/or reduced fetal growth during gestation. Numerous observational studies have identified the relationship between maternal smoking and increased risk of delivering low birth weight babies.[273] Since the 1980, researchers have investigated if a similar association exists between ETS and low birth weight. Results from a retrospective meta-analysis, conducted by *Windham, Easton and Hopkins* showed that parents, who were both nonsmoker and reported ETS exposure during pregnancy, were more likely to deliver a child who was small for their gestation age (SGA) (adjusted OR of 1.7, 95% CI, 0.83 - 3.4) and had a low birth weight at term (adj. OR 2.7 95% CI, 0.82-8.5).[274] Later, *Windham et al.*, affirmed their finding during a prospective study on 4,454 pregnant women. In this study, women who reported a high level of ETS exposure (≥7 hours for nonsmokers) not only had high rate of low birth weight deliveries (Adj. OR 1.8, 95% CI, 0.82-4.1), but also higher rates of preterm births (Adj. OR 1.6, 95% CI, 0.87-2.9) and very preterm births (<35 weeks) (Adj. OR 2.4, 95% CI, 1.0-5.3).[275] Results from the meta-analysis and the prospective study indicate a causal relationship between maternal ETS exposure and low birth weight deliveries.[276]

Cardiovascular Disease

Cardiovascular Disease (CVD) is the leading cause of death in the US. Within CVD, the primary cause of death is coronary heart disease (CHD) and stroke, together killing over 700,000 people in 2014.[277] Over the past three decades, numerous papers have shown that ETS exposure increases the risk for CHD mortality and morbidity, even after controlling for potential confounding factors. Building on previous research *Rosenlund et al.*, investigated the relationship between ETS exposure among nonsmokers and nonfatal myocardial infarctions (i.e. heart attacks). After controlling for age, gender, hospital catchment, BMI, socioeconomic status, job strain and health history, nonsmokers, whose spouse smoked on average 20 cigarettes per day, had a myocardial infarction OR of 1.58 (95% CI, 1.02-2.34).[278] An older study, by the American Cancer Society controlling for potential confounders only reduced the risk ratio (RR) for CHD from 1.97 to 1.71.[279] In total, the 2006 U.S. Surgeon General report on the impact of passive smoking identified seven cohort studies and four case-control studies that control for confounders, all of

According to the report, result from several case-control and cohort studies indicate that ETS exposure caused a 25 to 30% increase for CHD.

which saw modest reductions from the magnitude of their result.[280] According to the report, result from several case-control and cohort studies indicate that ETS exposure caused a 25 to 30% increase for CHD. Thus the Surgeon General's report concluded there is a causal relationship between exposure to ETS and CHD.[281]

Cancer

Lung cancer is the leading cause of cancerous death in the US. It is estimated the between 80 to 85% of lung cancer mortality is due to smoking.[282] Although the U.S. Surgeon General first reported the causal link between smoking and lung cancer in 1964, the first major epidemiologic studies showing the same relationship between ETS among nonsmoker and lung cancer were not published until 1981.[283] These first studies investigated lung cancer incidences among nonsmoker married to smokers versus nonsmokers married to nonsmokers. Result from studies conducted since 1981 identify a 24% increased risk for lung cancer in nonsmokers who live with a smoking spouse, with the risk increasing according to duration of the marriage and amount of cigarettes smoked by the spouse.[284] Results from a study examining ETS exposure among nonsmokers diagnosed with lung cancer in Asia reaffirm the dose-response relationship between ETS exposure and lung cancer, also suggest that childhood exposure significantly increased risk of lung cancer.[285] Radon, a naturally occurring radioactive gas, is the second leading cause of lung cancer after tobacco smoke.

Relative to smoking, radon exposure is a lower risk factor for lung cancer. However, when radon is inhaled with tobacco smoke, there is a synergistic effect.

Relative to smoking, radon exposure is a lower risk factor for lung cancer. However, when radon is inhaled with tobacco smoke, there is a synergistic effect.[286] Of all radon-induced lung cancer deaths, more than 85% are among smokers. EPA estimates that the lifetime risk of radon-induced lung cancer increases from 7 per 1000 to 62 per 1000 at the same level of radon exposure when comparing non-smokers to smokers.[287] As a result, there has been an increased focus on targeting smokers in radon control policies.

It has been firmly established that active smoking causes several other cancers beyond lung cancer. Whether this causal relationship hold for ETS exposure and other cancers has received less intention from researchers. One such study, conducted in 2000, examined whether the *N-acetyltransferase 2* (*NAT2*) genotype influenced the effects of passive smoking on breast cancer risk.[288] Results showed that when compared to lifetime nonsmokers with no exposure to ETS, lifetime nonsmokers exposed to ETS had an increased risk of breast cancer regardless of their NAT2 genotype status.[289] Similarly, a limited number of studies found ETS exposure among nonsmokers is associated with up to a three times the risk for nasal sinus cavity cancer.[290] Despite the limited studies, the U.S. Surgeon General concluded there is suggestive but not conclusive evidence that there is a casual relationship between ETS exposure and both breast and nasal sinus cavity cancer.[291]

Remediation

Smoke-free polices are the most effective method of reducing exposure to ETS in the home.[292] As of 2015, 27 states have implemented statewide smoke-free polices in all public buildings, worksites, and bars and restaurants.[293] From February 2017, HUD required all PHAs to implement smoke-free policies in federally-assisted public housing within 18 months. Despite these encouraging steps from federal and local government, many low-income households are still at risk for indoor ETS exposure. The 2017 HUD rule does not cover residents that rent through the Section 8 program or renters that occupy low-income private housing. Although residents may implement personal smoke-free policies within their homes, if a smoker resides in the building, they are still at risk for ETS exposure.[294] The following paragraphs describe how weatherization and energy efficiency retrofits can help reduce some components of ETS. However, neither activity alone can eliminate ETS from the home.

Ventilation and Air Exhaust

During weatherization, a buildings ventilation and air exhausts are upgraded to meet the most recent ASHRAE standards.[295] There is limited evidence indicating that improved building ventilation can reduce indoor ETS. A 2004 study examined the effectiveness improved ventilation and air sealing against ETS transfer amongst smoking and nonsmoking units in 6 Minnesota multifamily buildings. Using passive nicotine samplers, researcher found that nicotine levels were lower post invention for 3 of the tested buildings.[296] In 2010, a 500 unit 100% low-income Boston housing complex underwent extensive energy efficiency retrofits which included weatherization. The researchers examined how the building modifications impacted ETS PM2.5 transfer between smoking and nonsmoking units under several scenarios (i.e. windows open/closed, exhaust fans on/off).[297] In total, air filtrating and increased air supply decreased ETS PM2.5 infiltration by 40% during the winter months.[298]

Envelope and Unit Sealing

During the winter months, ETS infiltration from other units is heightened due to the thermal stack effect—the process that causes air to enter through building envelope cracks near the lower floors, rise through the building, and exit through crack in its path and the top of the building during the heating season. Both the above 2004 study and the 2010 study note that unit compartmentalization (i.e. sealing an apartment off from other apartments) and envelope sealing, in addition to ventilation, can reduce ETS infiltration between units. Compartmentalization and envelope sealing impedes ETS from entering the home on the ground floor and traveling up through building floors into other rooms and units.[299] Both approaches would be especially effective in large multifamily housing.[300] However, both studies suggest that compartmentalization and envelope sealing caused them to observe higher levels of ETS on the ground floor as both compartmentalization and envelope sealing can trap ETS on a building's lower levels.

Health Savings

There have been limited studies on the economic impact of remediation strategies on ETS exposure but there are studies on the impact of smoke-free public and subsidized housing. In 2011, between 37,791 and 50,967 child and adults residents of public housing were estimated to have experienced illness and death contributable to second-hand smoke, generating between $110 million and $153 million in direct medical costs.[301] Another study examining the impact of smoke-free policies in all U.S. subsidized housing revealed an estimated cost savings of $341 million per year in SHS-related health care and $521 million, when you consider renovation expenses and smoking-attributable fire losses.[302] While it is difficult to extrapolate ETS-attributable health savings, there is sufficient evidence to conclude that reducing ETS exposure would provide significant health benefits to residents, including decreased burden of child and adolescent asthma exacerbation and other respiratory diseases as well as reduced incidence of myocardial infarction.

INDOOR ENVIRONMENTAL ASTHMA TRIGGERS AND ALLERGENS

Asthma continues to be a serious public health problem. Significant disparities exist in the prevalence, management and health outcomes of asthma between racial, ethnic and socioeconomic populations. The disparities prompted the President's Task Force on Environmental Health Risks and Safety Risks to Children released the Coordinated Federal Action Plan to Reduce Racial and Ethnic Disparities in May 2012.[303] Research provides substantial evidence that residential environmental remediation, which reduces exposures to irritants, such as secondhand smoke; and allergens from house dust mites, pests, molds and animals, plays a significant role in improving asthma health outcomes. As described in the National Asthma Education and Prevention Program (NAEPP) "National Guidelines for the Diagnosis and Management of Asthma," environmental asthma trigger control strategies are an essential component of comprehensive asthma care.

Biological and Unsanitary Housing Conditions

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization Remove moldy objects from home Repair moisture intrusion points Repair/Improve home HVAC systems Improve home insulation Exterior repairs to downspouts, gutters, and grading to reduce water infiltration **Healthy Homes** Distribute allergen impermeable bedding Education on cleaning and washing protocols for furnishing and floors Use of dehumidifiers Removal of carpets Roof repair or replacement	**Reduced Environmental Toxins** Reduce the number of dust mites Lower levels of surface and ambient mold Lower levels of surface and ambient bacteria	**Lower Incidence of:** Asthma symptom days Asthma-related school and work absences Allergic reactions Asthma genesis Upper and lower respiratory illness Hospital admissions and emergency department visits	**RD-1-6** Respiratory diseases **EH-19** Reduce the number of occupied housing units that have moderate or severe physical problems	**Neighborhood & Built Environment** Quality of housing Environmental conditions **Education** Early childhood education and development School attendance **Health and Health Care** Access to primary care and health literacy

The following methods have been found effective in mitigating the presence of biological contaminants and unsanitary conditions inside of the home
Exhaust fans that vent to the outside of the house can be installed in kitchens and bathrooms to help avoid mold and moisture buildup and promote air circulation.
Vent clothes dryer to the outside of the house.
Maintain the relative humidity of the house between 30 and 50%.
Dry off wet surfaces and address water leaks.
Thoroughly clean and dry water damaged carpets and building materials within 24 hours, or consider removal or replacement.
Clean regularly to reduce presence of dust mites, pollen, animal dander, and other allergy causing agents.
Ventilate the attic and crawl space to prevent moisture buildup.
Minimize the presence of biological pollutants in basements through regular cleaning and the use of a dehumidifier.
Clean and maintain all appliances that directly contacts water including furnaces, heat pumps, central and wall air conditioning units, and humidifiers. Regularly change filters on heating and cooling systems.

Hazard Identification

Biological contaminates and unsanitary housing conditions often causes poor indoor air quality.[304] In housing, "biological and unsanitary conditions" refers to the presence of different combinations of bacteria, molds, viruses, animal dander, dust mites, bugs, or sewage that may lead to poor health. Indoor moisture supports the growth of unsanitary housing conditions above safe levels.[305] Moisture and water enter the home through structural leaks, damp foundations, inadequate ventilation, and through activities such as bathing or cooking.[306] Thus, sources of biological and unsanitary housing conditions are typically in bathrooms, basements, near wet appliances, and in some carpets and furniture. Biological contaminants can also grow in air conditioning systems, which may then distribute the contaminants throughout the home.

Health Effects

Unsanitary housing and biological contaminants within the home environment may trigger allergic reactions, rhinitis, and asthma. For asthma alone, it is estimated that home-based triggers cause 40% of asthmatic episode.[307] Although previous exposure to biological allergens may have occurred without incident, once a reaction occurs, re-exposure to that specific allergen will cause an allergic reaction. Exposure to biological contaminants during early childhood is uniquely harmful as it can lead to respiratory problems (coughing, rhinitis, bronchitis, wheezing, and difficulty breathing), and asthma development, which may increase utilization for related healthcare services.[308,309,310]

Mold

Indoor exposure to mold, fungi and moisture have been suggested as etiological agents of asthma.[311] Research shows that homes with higher values of the environmental relative moldiness index (ERMI), have been associated with childhood asthma.[312] Exposure to mold during early postnatal lung development can be particularly detrimental as it compromises airway growth, which can persist or worsen, even if exposure ceases.[313] Young children, because they spend most of their time indoors, are also vulnerable to the effect of mold.[314]

Poorly maintained HVAC systems can facilitate mold growth in homes. A study of crawl spaces in homes found that mold transmission from crawl spaces into the indoor environment was present in 19% of homes assessed. Another study found that homes with central AC were associated with 2.5 less points on the moldiness index (95% CI=-4.7, -0.4). The researchers did not control for socioeconomic status, family income or building age, therefore we cannot conclude a causal relationship between central AC and the decrease.[315] Regardless, low-income residences are more likely to exhibit the architectural and HVAC system deficiencies that increase the likelihood of mold transmission. Thus conducting more research on this area could yield important implications for HVAC systems and low-income housing.[316]

Pollution

Because of the "grasshopper effect—migration of pollutants from the warmer outdoors to the cooler indoors—outdoor pollution may affect indoor exposure to chemicals.[317] These chemicals can be inhaled, absorbed through the skin, and ingested.[318] Children living in unsanitary housing conditions in cities face greater incidents of exposure than children living outside of cities. A Baltimore study that collected indoor air pollutant and allergen data from 100 homes found asthmatic children were exposed to elevated indoor air pollutant and allergen level, with inner city children experiencing a higher asthma burden compared to non-inner city children.[319] Children living in or near agricultural communities can have a greater risk of exposure to outdoor pollutants because caregivers who work in the agricultural industry can carry pollutants into the home after they return from work.[320]

Remediation

Home environmental conditions are contributors to allergies and asthma; therefore, proven in-home intervention methods can reduce human exposure to biological contaminants and unsanitary housing conditions, and their associated morbidities. A 2010 review of housing interventions that tackle health outcomes associated with exposure to moisture, mold, and allergens found that multifaceted, in-home, tailored interventions combined with the elimination of moisture intrusion points in the home and the elimination of moldy items reduced asthma morbidity and respiratory allergies.[321] Figure 3 (below) describes this approach.[322]

Multifaceted, in-home, tailored interventions use a varied approach to decrease residential exposure to multiple asthma triggers, reduce asthma symptoms and short term health care utilization, and improve quality of life.[323] Interventions may include an in-home environmental assessment, resident education, mattress or pillow cover distribution, high-efficiency particulate air (HEPA) filtration systems installation, home repairs, ventilation improvement and integrated pest management, and removing pets. Figure 4[324]describes methods that have been found to be effective in mitigating the presence of biological contaminants and unsanitary conditions inside the home.

Multifaceted, in-home, tailored interventions use a varied approach to decrease residential exposure to multiple asthma triggers, reduce asthma symptoms and short-term health care utilization, and improve quality of life.

The Inner City Asthma Study, a large randomized trial examining various asthma trigger interventions among children, provides the strongest evidence of the effectiveness of a multifaceted approach. The study showed a reduction in asthma symptom days, and a reduction in emergency room and clinic visits.[325,326,327] Home visits by community health workers as a means to support families in decreasing their asthma triggers also resulted in significantly reduced use of urgent care services.[328] Similarly, Breysse et al., found that nurse case manager combined with interventions that promote collaboration between health and housing professionals is effective in reducing exposures to allergens in settled dust.[329]

Another study retrospectively examined health care utilization of pediatric patients that had a home environmental assessment recommended by a pediatric allergist as part of a comprehensive case management program. (The program included education, clinic visits, an environmental assessment, and case management.) In the year following the combined home assessment/case management, as a whole participants experienced fewer hospitalizations, ER visits, and clinic visits, suggesting that a combination of home assessment and case management may reduce medical care utilization for children suffering from asthma and allergies.[330]

HOUSING INTERVENTIONS TO CONTROL INDOOR BIOLOGICAL AGENTS

Intervention ready for implementation	Short-term objectives	Mid-term objectives	Long-term objectives	Goal
Promote multifaceted, in-home, tailored interventions for asthma	Increases behaviors to maintain control of asthma triggers in homes	**Reduce exposure to multiple asthma triggers:** Mold Mites Roaches Rodents Pet dander Tobacco smoke	Reduce asthma morbidity (symptoms, ED visits, hospitalizations, school and work absenteeism, etc.)	People with asthma living free of asthma symptoms and disability
Promote combined elimination of moisture intrusion and leaks and removal of moldy items	**Remediate conditions leading to trigger exposure:** Moldy objects Moisture sources Trigger reservoirs Pest entry points			
Promote cockroach control through integrated pest management				

Many studies have suggested that interventions that decrease exposure to mold can lead to positive health results, including decreased allergic symptoms.[331,332,333] Ventilation can control the moisture that causes mold. Installing a whole-house mechanical ventilation system can reduce the humidity in a home, reduce the number of dust mites, decrease allergen levels, and improve overall health.[334] In temperate climates, dehumidifiers have been shown to be effective in reducing dust mite levels.[335] Ventilation can also decrease the levels of indoor contamination.[336] Improved insulation also decreases mold and moisture prevalence in a home, improving general and respiratory health issues.[337] Studies have shown that HVAC systems can be effective at alleviating asthmatic symptoms and development. One longitudinal study followed a high-risk group from infancy to age seven. Although the study focused only on the impact of Environmental Relative Moldiness Index (ERMI) on asthma development, the study also identified a clear inverse correlation between air conditioning and asthma development (OR, 0.3; 95% CI, 0.14-0.83).[338] Similarly, another study found that home remediation (which included HVAC systems alteration) resulted in reductions in asthmatic morbidity, a significant decrease in symptom days (p = 0.004) and less exacerbations (1 of 29 vs. 11 of 33, respectively, p = 0. 003).[339]

Studies that apply a singular intervention (i.e. bedding encasement installation only) have been shown to be less effective than a multifaceted approach.

Intensive vacuuming and steam cleaning of carpeting and furnishings have shown reductions in the levels of dust, dust mites, and animal allergens in a home. HEPA air filtration systems have also been shown to be effective in removing pet allergens, but may be less effective in addressing mites and mold. However, HEPA filters in combination with the installation of allergen-impermeable bedding encasements and upholstery cleaning may reduce allergen levels in the home.[340] Further research is still need on the effectiveness of one-time professional cleaning.[341]

Studies that apply a singular intervention (i.e. bedding encasement installation only) have been shown to be less effective than a multifaceted approach. However, it is important to note that the effectiveness of these interventions may vary by region, climate, and level of compliance from residents.[342]

The WAP guidelines allow for the remediation of conditions that may lead to or promote biological concerns and unsanitary conditions. Measures target structural issues that contribute to moisture and mold growth in the home, however very severe mold issues are currently beyond the scope of WAP interventions.[343]

Health Savings

Some in-home biological contaminants and unsanitary conditions interventions have shown a very rapid payback. A 2009 study found evidence that home visits designed to reduce the exposure of children with poorly controlled asthma returned more than a 100% investment in one year in terms of reduced healthcare costs.[344] In this study, home visits provided access to vacuum cleaners with dirt finders and HEPA filtration systems, allergy control bedding covers, high-quality doormats, and air filtration systems. Typical vacuums allow deep dust to build up in carpets, which can be disturbed as a result of regular activity on the carpet. Vacuums with dirt finders allow users to monitor deep dust, which can improve and reinforce more effective cleaning habits. The study also found that interventions that include an in-home visit from a trained outreach worker improved the overall effectiveness and were relatively low cost considering the reduction of the risks that were achieved.[345]

A review of six asthma interventions that utilized minor to moderate measures found that three of the studies reported cost benefit ratios between $5 and $14, indicating substantial returns for each dollar invested. The remaining three studies reported cost-effectiveness costs between $12 and $57 per additional asthma symptom-free day, which the literature on cost effectiveness considers good value.[346]

A sub-analysis performed as part of the National Evaluation of the DOE's WAP investigated the asthma-related health impacts of weatherization and healthy homes interventions using data from households in Washington State between 2006 and 2013. Results indicated that medically-insured households that received either weatherization, healthy homes or weatherization plus healthy homes renovations significantly decreased their health care utilization post intervention. Together the participants' average yearly asthma-related Medicaid cost decrease by $421.

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization Sealing moisture intrusion points **Healthy Homes** Integrated Pest Management Distribute allergen impermeable bedding Education on Cleaning and washing protocols for furnishing and floors	**Reduced Environmental Toxins** Lower numbers of Pest: Cockroach, rodents, and dust mites.	**Lower Incidence of:** Asthma symptom days Asthma related school and work absences Allergic reactions Asthma genesis Rodent related infections Hospital Admissions	**EH-19** **RD-1** **RD-1.1** **RD-2** **RD-2.1** **RD-2.2** **RD-3** **RD-3.1** **RD-3.2** **RD-4** **RD-5.1** **RD-5.2** **RD-6**	**Neighborhood & Built Environment** Quality of housing Environmental conditions **Education** Early childhood education and development School attendance **Health and Health Care** Access to primary care and health literacy

Pest Management

Hazard Identification

Pest infestations (i.e. mice, rats, cockroaches, and dust mites) can trigger or exacerbate asthma symptoms and allergies, especially among children in high poverty areas, and public housing.[347] Pest excrements are particularly harmful to inhale. Rodent-borne diseases are easily transferred to humans through direct handling, bites, scratches, or fleas.[348] Inhabitants of humid climates are more susceptible to the bacteria carried by rodents because humidity fosters bacterium proliferation and allow bacterium to survive outside their rodent host. Seasons, like climate, also impact susceptibility. In agricultural environments, the peak infectious mice rates occur between January and April, whereas in urban areas peak infectious rates last from February to July.[349] Living in rural areas during infancy is inversely correlated with allergen sensitization later in life.[350]

Health Effects

Rodents

Humans can contract rodent-borne disease by inhaling the virus particles that are shed in rodent feces, urine, or saliva. The frequently fatal Hantavirus cardiopulmonary syndrome (HCPS) is transmitted through rodent secretions and excretions.[351] Rat bite fever is transmitted through scratches, bites, or ingesting rat feces contaminated food.

Asthma diagnoses are also positively correlated with mouse infestations.[352] In addition, rodent infestations can cause mental stress, and property damage, which can be especially burdensome for low-income residents.[353]

Cockroaches

Sensitivity to cockroach allergen (CRa) can begin in childhood and in many cases may be the only sensitizing allergen for children living in urban areas.[354] Cockroach allergies are often responsible for asthma or other atopic diseases, and are typically associated with house dust mite (HDM) allergies. Similar to rodent diseases, cockroach sensitivity is disproportionately observed among low-income urban children.[355] Additionally, research confirms these same populations also struggle with economic burdens, missing school, and sleep deprivation. High asthma hospitalization rates have been observed in children with cockroach allergies.[356] In cockroach-infested areas, more than 50% of asthmatics experience positive skin reactions indicating sensitivity to cockroach allergens.[357]

Dust mite allergens are the only type of inhalant allergen for which the National Academy of Sciences could find evidence of a causal association between exposure and the development of asthma.

Dust/Dust Mites

Dust is the main conduit of childhood exposure to allergens, lead, pesticides, and carcinogens.[358] Children's activity patterns (time spent near/on the floor) and lower breathing zones yield greater rate of dust ingestion and the associated health risk compared to adults.[359] Dust mite allergens are the only type of inhalant allergen for which the National Academy of Sciences was able to find evidence of a causal association between exposure and the development of asthma.[360] House dust mites thrive indoors, specifically in kitchens and bedrooms, and are commonly found in bedding, carpeting, and upholstered furniture. Although detectable dust mite allergens levels are found in more than 80% of U.S. homes, housing with biological and unsanitary conditions can contain larger concentrations.[361]

Dust mites feed on organic debris such as shed human skin flakes, and can flourish in homes, schools, and work buildings. Dust samples from carpets and mattresses typically indicate dust mite level in the home.[362] Poor indoor air quality encourages dust mite allergies, which usually co-occurs with other indoor allergies.[363] Dust mite allergies are caused by repeated inhalation and can survive in the lungs for some time.[364] In developed countries, approximately 30% of the general population suffer from one or more allergic disorders.[365] Perennial rhinitis, the most commonly allergic disorder, is often attributed to a house dust mite (HDM) allergy.[366] Additional HDM allergy symptoms include bronchial hyper-reactivity, rhinitis, bronchitis, coughing, wheezing, dyspnea, increased stress, post-nasal drip, nasal discharge, congestion, irritated eyes, headache, itchy ears, and night disturbances.[367]

In an effort to detect differences in the concentration of airborne mite allergens in AC filter-nets, a group of researchers measured concentrations in homes before and after ACs were switched on. Allergens significantly increases after ACs were switched on, confirming the existence of mite allergens in the air conditioners filter-net dust.[368] Additionally, a study on the relationship between ACs in the workplace and usage of health services due to illness, found sickness absences and visits to otorhinolaryngologists (specialists in ear, nose, and throat) were significantly higher in workplaces with ACs.[369]

Remediation

Integrated Pest Management (IPM)

As causes of asthma and allergies are multidimensional, "broad-based" interventions that address multiple allergens at once are more successful than tackling each allergen individually.[370] Integrated Pest Management (IPM) has been proven effective in reducing levels of pests and associated allergens.[371] IPM combines pesticides and baits with a long term plan aimed at preventing re-infestation and removing the homes structural conditions that contribute to infestation.[372] *Peters et al.* found a decrease in allergen levels six months following IPM implementation.[373] A 2009 study compared IPM interventions in 8 buildings with 5 buildings (280 apartments total) that used pesticide and insecticides only. After 6 months, the IPM treated buildings reported statistically significantly lower levels of cockroach allergens compared to the control group.[374]

Rodents

The IPM strategy includes common rodent control methods, pest education, environmental hygiene, rat indexing, access reduction, and trapping. Community cooperation is especially important when controlling rodent infestation. Environmental hygiene improvements, such as garbage collection, storage room cleanliness, and empty space and resource recycling station hygiene are critical in rodent control.[376] In 2012, New York City successfully used rat indexing (proactive inspections, education, and outreach) at the community level over a 21-month period. During this time, the percentage of properties with infestations declined significantly.[377] Eliminating rodent access, harborage, and food sources also decrease rodent infestation.[378] Traps are equally effective at removing rodents and safer for humans than toxic, sometimes illegal, pesticides.[379]

Cockroaches

Cockroach remediation methods include cleaning, bait traps, insecticides, and exposure reduction. A 2003 study that compared the techniques of professional cleaning, bait traps with insecticide, and bait traps without insecticide, found that intensive cleaning has the ability to reduce cockroach allergens in heavily infested homes but without traps, levels may still remain high.[380] Another study demonstrated that a combination of home-based education, cockroach extermination, mattress and pillow encasings, and high-efficiency particulate air cleaning resulted in a 51% decrease in cockroach allergen levels.[381]

Dust Mites

Dust mite numbers in the home are reduced through avoidance, education, cleaning, bedding improvements, and physical structure improvements. A study noted that avoidance in infancy reduces allergic sensitization and may prevent some cases of childhood asthma.[382] Asthma management education is also critical. Families that see an allergist demonstrated significantly greater levels of awareness of and control over dust mite allergens than those who had not.[383] Education can also reduce stress and increase compliance with healthcare regimens in patients with dust mite allergic asthma.[384]

Vojta et al. demonstrated that steam cleaning and vacuuming can effectively reduce house dust mite allergen concentrations.[385] Intense cleaning can keep post-treatment HDM allergen levels lower than the pretreatment levels for 4-8 weeks. Furthermore, mattress encasement can significantly decrease allergen levels when combined with professional or in-home cleaning.[386] Other effective techniques include replacing foam mattresses with spring mattresses,[387] using feather rather than synthetic bedding items,[388] or replacing or vacuuming the mattress more than twice per year.[389] Using dust mite impermeable bedding may also reduce allergen levels, but is most effective when coupled with other preventative measures.[390]

Reducing pests and indoor allergens has been found to reduce needed medical treatment through emergency room visits, hospitalizations, doctor visits, and medication costs.

Home structure improvements can also decrease levels of house dust mite allergens. Controlling humidity levels in the home is essential, as dampness, ventilation levels, and bedroom temperature are associated with the presence of dust mite feces.[391] Mites thrive in humid areas,[392] therefore humidity regulation can effectively control allergens.[393] The WAP guidelines only allow for reasonable measures to remove pests from the home.[394] According to Crocker et al. integrated pest management, which combine some aspects of the aforementioned remediation, is currently considered a moderate intervention.

Health Savings

Reducing indoor allergens can reduce costs, severity, and the risk of being sensitized and developing allergic disease. Between 2001 and 2010, U.S. asthma incidence for adults increased from 7.3% to 8.4%, with rates among children under 18 years reaching 9.5%.[395] Asthma related health care encounter rates per 100 asthmatic people remained flat between 2007 and 2009, with similar rates observed between genders and across ethnic groups; however, rates for children were almost double the rates for adults.[396] Furthermore, blacks are twice as likely to visit the ED compared to whites.[397] Reducing pests and indoor allergens has been found to reduce needed medical treatment through emergency room visits, hospitalizations, doctor visits, and also medication costs.[398] A 2005 study reported that reducing pests and indoor allergens over a two-year period reduced the amount of sleep missed by parents/guardians of asthmatic or allergenic children and reduced in school days missed by asthmatic or allergenic students. In addition, the risk of hospitalization decreased.[399] Reducing pest numbers can also lower the stress, property damage, and financial loss associated with infestations for residents. These findings demonstrate how reducing indoor pests results in both short-term and long-term health improvements and financial savings.

COMFORT & SAFETY

Thermal Comfort

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization **Insulation:** Improve home's insulation **Ventilation:** Increase the volume of indoor to outdoor air exchanged **Healthy Homes** Education on HVAC maintenance protocols	**Thermal Comfort** Improved indoor climate	**Lower Incidence of:** Thermal stress related CVD emergency room visits and hospitalizations Thermal stress related hospitalization and death	**HDS-2** Reduce coronary heart disease deaths	**Neighborhood & Built Environment** Quality of housing Environmental conditions **Health and Health Care** Access to primary care and health literacy

Hazard Identification

Thermal comfort improves productivity, lowers mortality, and is a well-established benefit in research findings. The collective evidence demonstrates how housing interventions lower mortality rates, especially for vulnerable populations, by reducing exposure to temperature extremes and the resulting thermal stress. Both exposure to extreme heat and cold are known to cause thermal stress that leads to increased mortality rates. The elderly, those in poor health, and the poor are known to be more vulnerable to both exposure to temperature extremes and the negative health effects produced by preventable exposure.[400] Exposure to either extreme heat or cold can directly cause death. Extreme heat combined with high humidity can also exacerbate existing cardiovascular disease (CVD), diabetes, respiratory problems, and hypertension.[401] Additionally, extreme cold is equally dangerous, since chronic extreme cold exposure is also known to exacerbate CVD and other respiratory disorder.[402] Cold exposure is further complicated because its impact often take weeks to manifest.[403] Both extreme heat and cold exposure can be attributed to inadequate temperature controls in the home, while extreme cold exposure is additionally facilitated by poor home insulation.

Additional hazards arise when occupants are exposed to poorly maintained air conditioning (AC) systems, which can exacerbate other health hazards. Poorly maintained AC systems can allow the infiltration of outdoor pollutants or the growth of potentially harmful organisms on cooling coil and humidification components.[404] The high moisture content of AC components makes them suitable breeding grounds for various contaminants, which are then disseminated throughout the building through the ventilation system. These contaminants include bacteria, molds, mildew, viruses, pollen, and animal dander – all of which can be distributed by heating, ventilating and air conditioning (HVAC) systems.[405] In general any contaminant could be spread by HVAC units, there are an innumerable variety of health problems and possible hazards that can be indirectly exacerbated. Many hazards are understudied, yet the literature has consistently linked HVAC wet cooling systems (which can aerosolize contaminated water) with Legionnaire's Disease – a pneumonia caused by the bacterium Legionella pneumophila.[406]

Climate change is increasing the frequency and potency of extreme weather events. Measurements show that the global mean temperature during the first decade of the 21st century was 0.8°C (1.4°F) warmer than the first decade of the 20th century. The increase in global temperature has been correlated with more reports of prolonged heat waves and shorter cold spells.[407] Gram-Negative Bacteria, a climate related bacteria group, infects humans through water consumptions (inhalation or ingestion). Legionella pneumophila, a gram-negative bacterium, has been identified to be correlated with summertime reports of increased relative rainfall and humidity in the previous week.[408] It is also an opportunistic bacteria; therefore, older people, and persons with weak immune system or existing lung disease are more likely to development symptoms after exposure.[409] It is not clear if increased rainfall grants extra access to the water supply or if humidity increases the bacteria's survival.[410] Regardless, climate changes will likely increase humidity and temperature during the summer months among eastern U.S. states, increasing the outbreak incidence of legionella and other related bacteria.

Health Effects

A person's ability to withstand thermal stress depends on several factors, most notably age. The peripheral nervous system regulates the body's reaction when it gets too hot or cold, yet as a person ages, their peripheral nervous systems deteriorates. As the peripheral nervous system deteriorates, a person's sensitization to thermal stress decreases and their ability to take steps to reduce body temperature slows. Sweat production slows with age, decreasing our ability to lower our body temperature. A review of 43 heat waves events that occurred between 1987 and 1995 found that mortality rate increased an average of 3.74% on heat days compared to non-heat days. In Maricopa County, Arizona, between 2000 and 2008, heat exposure was directly responsible for 73% of deaths during the summer period.[412] Although many residents died during periods of extreme heat, deaths still occurred when the day's temperature was below the median seasonal temperatures.[413] According to a 2011 study on the 2010 U.S. Census, the top largest age groups in the U.S. are the 25-44 group and the 45-64 group.[414] This suggests that the number of people, who have less resilience to thermal stress, will only increase.

Thermal stress can also complicate other chronic conditions. Several studies have found links between increased mortality during heat waves and cardiovascular diseases prevalence.[415] During the 2003 European heat wave, the mortality rate for people with CVD increased by 30%.[416] CVD was prominent among the chronic diseases blamed for the excess death rate during the 1995 Chicago heat wave. Those with diabetes, roughly 10% of the U.S. populations, suffer more during heat waves.[417] Many diabetic people suffer from neuropathy which hinders the body's sweat response. Sweating can cause diabetic people's fluid and electrolyte to be unstable, which disrupts glucose regulation. These factors contributed to the increased mortality rate among diabetics during the 1966 New York heat waves.[418] Similarly, those with existing pulmonary condition are more likely (OR, 1.61; 95% CI, 1.2-2.1) to die during heat waves.[419]

Several studies have shown that those with existing chronic conditions are at a heightened risk during cold episodes. In Toronto, Canada, researchers examined 292,666 and 562,738 emergency room (ER) visits for CVD and respiratory diseases, respectively.[420] Analysis revealed extreme cold temperatures effect on CVD ER visits were larger for individuals with existing cardiac diseases (REM = 1.47; 95% CI: 1.06 – 2.23) and kidney diseases (REM = 2.43; 95% CI: 1.59 – 8.83) compared to individuals without these co-morbidities.[421] A meta-analysis of daily mortality and weather data for over 6 million deaths that occurred in the U.S. cities between 1989 and 2000 found that extreme cold exposure was associated with a 1.59% increases in daily mortality after a 2-day lag.[422] Extreme cold exposure was also associated with a 3.9% and 16.2% increase of myocardial infarction and cardio arrest mortality respectively.[423]

Increased air conditioning prevalence is the most effective method at reducing extreme heat exposure in the home.

Thermal stress has also been known to impact those living with sickle cell disease (SCD) more than those without sickle cell disease. Sickle cell patients have a hypersensitivity to heat and cold characterized by significantly lower median cold (29.5°C vs 28.6°C, P = 0.012) and heat (34.5°C vs 35.3°C, P = 0.02) detection thresholds as well as significantly lower median cold (21.1°C vs 14.8°C, P = 0.01) and heat (42.7°C vs. 45.2°C, P = 0.04) pain thresholds.[424]

Remediation

Increased air conditioning prevalence is the most effective method at reducing extreme heat exposure in the home.[425] The WAP technical manual recommends repairing or replacing inoperable or inadequate AC systems, especially when the unit's climate location leaves them at increased risk.[426] A meta-analysis of heat related mortality rates in 4 U.S. cities found that for every 10% increase in central AC unit prevalence, heat related deaths fell 1.4%.[427] Surveys indicate that issued heat warnings are heard by the majority of the population but this knowledge does not translate in behavioral changes.[428] The knowledge-behavior disconnect can be attributed to citizens underestimating their own vulnerability and risk.[429] Weatherization interventions can protect occupants when they are not aware of their own risk for heat aggravated health problems.

Heat reflective weatherization measures can also reduce the risk of extreme heat exposure. Researchers conducted two computer simulations modeling the temperatures of top floor units in two story MF buildings without AC; one with the windows open and with them closed. Findings showed that top floor temperatures remained high even after the outdoor temperatures began to fall. When the simulation was repeated with attic insulation and white roof paint installed, the open window simulations showed the top floor temperatures fell in line with outdoor temperatures.[430]

Reducing domestic heat seepage through energy efficiency retrofits is the most effective means to reduce cold related mortality and morbidity. WAP services include energy efficiency measures such as ceiling and duct insulation, envelope sealing and furnace tune-ups/repairs.[431] Analysis of wintertime indoor temperatures among WAP recipients' pre and post-weatherization found that the mean temperature (70.3°F) rose 0.14°F, whereas the control groups mean temperature fell.[432] Households who had pre-weatherization indoor temperatures at the edges for the sample's range (60-80°F) saw their indoor temperatures regressed to the sample's mean post- weatherization temperature.[433] A review of WAP homes found there was a 2.1 percentage-point drop in cold related medical incidents 12 months post weatherization.[434]

Health Savings

Due to climate change, heat waves and extreme heat episodes are predicted to increase negative health outcomes and health care costs. Consequently, the cost and risk of heat related health emergencies will increase accordingly.[435] *Kalkstein and Greene* calculated that climate changes will more than double the number of heat related deaths between 2020-29 and 2090-99.[436] Reducing thermal stress among residents would not only reduce the incidence of heat-related mortality and mobility, it would also confer substantial savings for individuals and society. Oak Ridge National Laboratory (ORNL) calculated that the WAP generated $870 in thermal heat stress benefits per unit weatherized. Benefits included savings due to death prevention.[437] Another WAP evaluation calculated that insurance companies could avoid over $189,000 in medical cost payouts for heat related hospitalizations, and save over $361,000 on emergency room payouts.[438] Together homes weatherized in 2008 through WAP saved an estimated total of $16,000 in out-of-pocket expenses for heat related hospitalization.[439]

Climate change is also hypothesized to increase weather fluctuations between extremely hot and extremely cold weather.[440] Weatherization services have the potential to reduce cold-related medical expenses in addition to mortality. ORNL calculated that the WAP generated $3,911 in thermal cold stress related benefits per unit weatherized. $3,739 of the benefit is a result of avoiding death.[441] Also the WAP evaluation found that the intervention enabled residents to avoid a combined total of $87,428 in out of pocket hospitalization fees and $53,918 in emergency room fees.[442]

Correctly functioning HVAC systems can have positive influences on health. Directly, HVACs can mitigate the effect of extreme heat episodes by lowering a buildings temperature. *O'Neil Zanobetti, and Schwartz* (2005) found that AC utilization lowered heat associated mortality among four major U.S. cities.[443] Additionally, another study found that AC usage significantly reduced cardiovascular disease, ischemic heart disease, heat stroke, diabetes, and acute renal failure, even when controlled for socioeconomic factors like family income.[444]

Evidence from national surveillance shows the leading causes of unintentional home injury deaths include falls, poisonings, drownings and fire/burns, which comprise an estimated 86% of unintentional home injury deaths.

Home Safety: Unintentional Injury and Fall Prevention

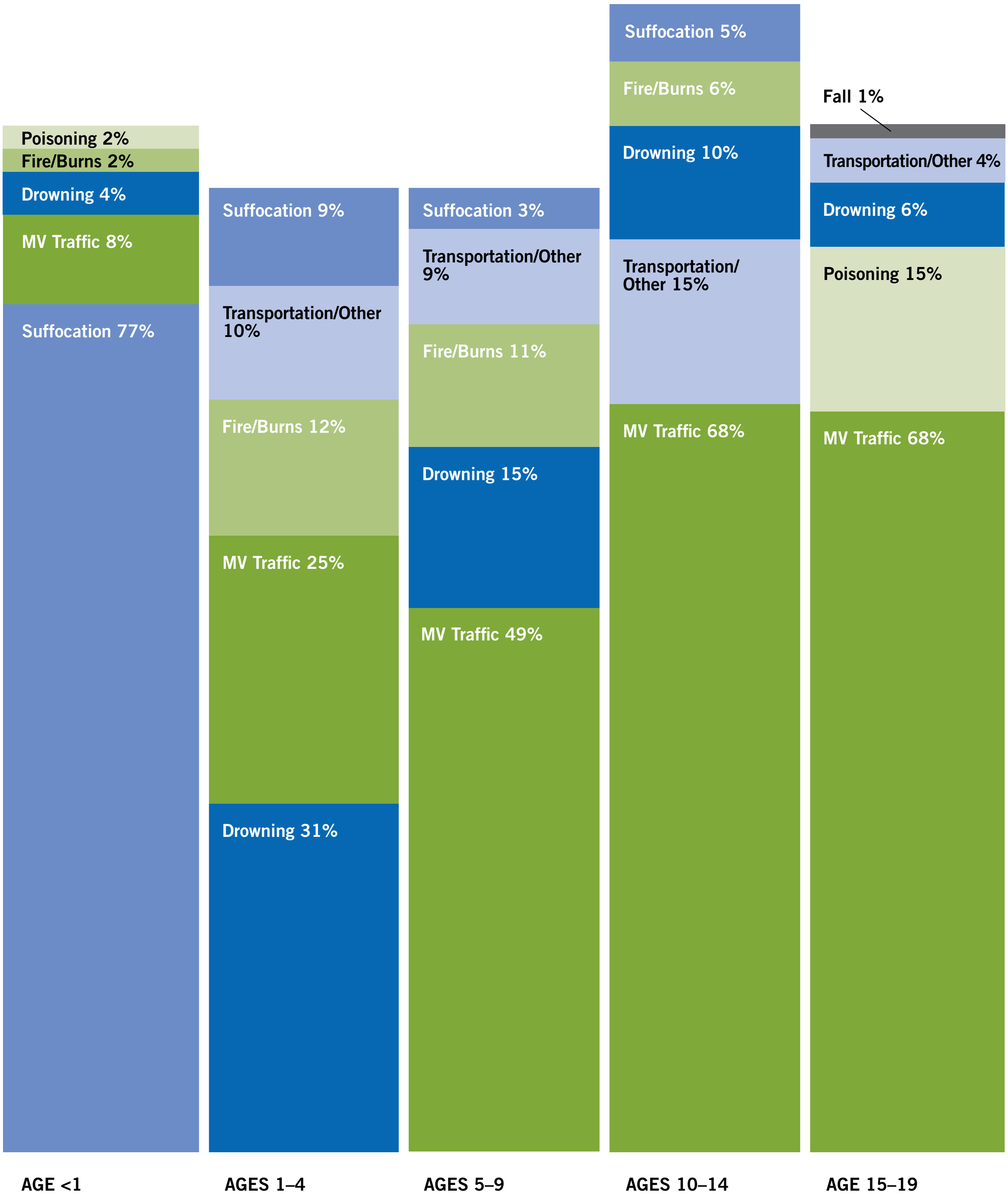
Hazard Identification

The World Health Organization (WHO) defines injury prevention as "the actions or interventions that prevent an injury event or violent act from happening by rendering it impossible or less likely to occur", whereas "intentionality distinguishes violence from unintended events that result in injury".[445] Injury Prevention (IVP-1.1) is considered a leading health indicator (LHI) by Healthy People 2020. This national public LHI aims to reduce the national rate of fatal injuries from 59.7 (2007) to 53.7 deaths per 100,000 population. Evidence from national surveillance shows the leading causes of unintentional home injury deaths include falls, poisonings, drownings and fire/burns- which comprise an estimated 86% of unintentional home injury deaths.[446]

UNINTENTIONAL INJURY PREVENTION

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Fall prevention Encapsulation (covering lead paints with a neutral paint barrier), Enclosure (covering paint with a rigid barrier) Window replacement and/ or Window treatments **Healthy Homes** Education on home safety practices, maintenance and repair protocols	**Improve Home Safety for Children** **Reduce Falls in Older Adults**	**Lower Incidence of:** Falls Poisonings Drownings Suffocations	**IVP-11** Reduce unintentional injury deaths **IVP-1** Reduce nonfatal unintentional injuries **IVP-23** Prevent an increase in fall-related deaths **IVP-24** Reduce unintentional suffocation **IVP-25** Reduce drowning deaths	**Neighborhood & Built Environment** Quality of housing Environmental conditions Crime and violence **Health & Health Care** Early childhood education and development School attendance and health literacy

FIVE LEADING CAUSES OF UNINTENTIAL INJURY RELATED CHILD DEATHS, BY AGE GROUP, UNITED STATES, 2009



Therefore, unintentional injuries that occur in the home environment are an important driver behind the national trend that has led home injury deaths and rates to increase significantly from 2000 to 2008 and are, therefore, included among the leading health indicators for national prevention efforts.

An analysis of U.S. population health statistics shows from 2000 to 2008, there was an annual average of 30,569 unintentional injury deaths occurring in the home environment in the U.S. (10.3 deaths per 100,000); poisonings (4.5 per 100,000) and falls (3.5 per 100,000) were the leading causes of home injury deaths.[447] The same analysis found evidence of health disparities since men/boys displayed higher rates of home injury death than women/girls (12.7 vs 8.2 per 100,000), and older adults (≥80 years) had higher rates than other age groups. In HP2020, there are specific objectives related to preventable injuries among the Injury and Violence Prevention topics: IVP-11, reduce unintentional injury deaths from 40.4 deaths (2007) to 36.4 per 100,000 population, and IVP-12, reduce unintentional nonfatal injuries from 9,233.5 (2007) per 100,000 population of emergency department (ED) visits for nonfatal unintentional injuries to 36.4 per 100,000 population.

The burden of unintentional injuries on American society is significant and remains the leading cause of death for Americans ages 1 to 44 and a leading cause of disability for all ages, regardless of sex, race/ethnicity, or socio-economic status.[448] Following motor vehicles, the home environment is the second most common location for fatal injuries in the U.S. and therefore a significant burden to public health.[449] Within the home environment there are approximately 30,000 unintentional injury–related deaths at home each year, and there is an average of 21 million medical visits[451] made each year because of home injuries.[452] However, most unintentional injury events that result in injury disability or death are preventable, and the CDC has estimated that annually more than 11,000 deaths occur within the home environment are preventable unintentional injuries.[453]

Unintentional	Intentional
Road Traffic Injuries	Interpersonal- Family/Partner (intimate partner, child or elder abuse)
Poisoning	Interpersonal- community (acquaintance, stranger)
Falls	Self-Directed (suicidal behavior, self-harm)
Fire and burn injuries	Collective Violence – social, economic, political (war, gangs)
Drowning	
Other	

Source: CDC. National Action Plan for Child Injury Prevention. https://www.cdc.gov/safechild/pdf/national_action_plan_for_child_injury_prevention.pdf

The first principle of injury prevention is that injuries occur as the result of events, either intentional or unintentional, however the primary difference is many unintentional injuries can be predicted and prevented.[454] Unintentional injuries that occur in the home environment are related to many factors that span individual, interpersonal, organizational, community, and societal determinants.[455] In this section, we will identify the evidence related to home safety hazards that are leading causes of the unintentional injury deaths, disability and morbidity in society and will focus on home safety for children and fall prevention for older adults.

Child Home Safety

The major types of injuries resulting from home safety hazards for children include poisonings, drownings, falls and fire and thermal injuries. For the HOME study, *Phelan et al (2010)* identified home injury hazards to include: tap water temperature exceeding 120 degrees Fahrenheit, absent or non-functioning smoke alarms or carbon monoxide detectors, accessible and unlocked cabinets and drawers, unstable furniture or television stands, poorly maintained or un-gated and accessible stairways, unsecured area carpets or rugs, accessible stove tops and ovens, easily accessible medications, cleaners, detergents, poisons, or sharps, accessible windows (inside ledge 4 feet above ground), uncovered electrical sockets, lack of poison control or clinic phone numbers, and unsafely stored firearms (no trigger lock or lock box for storage and/or ammunition not kept separate from firearm).[456] This childhood home hazard list was based on the national analysis of the leading mechanisms of injury resulting in an emergency visits which are falls, cut/pierce, struck/strike, poison and burn.

In a review of intervention strategies to prevent unintentional injuries in the home, *Mack et al.* reported that the risk factors are male gender, low socioeconomic status among children, and young age (≤6 years old).[457] The same review identified important fall-related hazards for children in the home as baby walkers, stairs, windows above ground level, bathrooms, and certain furniture. Unsafe beds, specifically were identified by *Mack et al* as the leading home product involved in injuries in infants, and in the percentage of nonfatal home injury costs for children under 5 years of age. The review also identified the most important residential hazards associated with falls among children as a lack of safety devices such as properly installed and used safety gates or window guards and structural defects (e.g., uneven floors; insufficient surfacing under play equipment).

Fall Prevention in Older Adults

Falls are the leading cause of fatal and non-fatal injuries among older adults who are 65 years and over. A recent consensus statement among experts defines a fall as "an unexpected event in which the participant comes to rest on the ground, floor, or lower level".[458] For older adults, which is and will be a growing demographic, deaths from falls increased from 2000 to 2008, from an age-adjusted rate of 2.6 per 100,000 in 2000 to 4.2 per 100,000 in 2008 ($p<0.000$).[459] Another systematic review (Deandrea 2010) estimated 15% of falls result from an external event that would cause most people to fall, a similar proportion have a single identifiable cause such as syncope, and the remainder result from multiple interacting factors (Campbell 2006).[460] CDC has reported, for fall injuries among older adults, an estimated 2.8 million emergency visits and over 800,000 patients a year are hospitalized because of a fall injury, most often because of a head injury or hip fracture.[461] Research findings have also reported 20% of falls cause a serious injury such as broken bones or a head injury.[462] Overall more than 95% of hip fractures are caused by falling,[463] usually by falling sideways;[464] and falls are the most common cause of traumatic brain injuries as well.[465]

CDC reports injury researchers have identified many risk factors that contribute to falling. Older adults face multiple fall risk factors and have more comorbidities as they continue to age. An older adult with more risk factors has a greater risk of falling. To prevent falls, interventions should focus on modifiable risk factors which include: lower body weakness, poor vision, difficulties with gait and balance, and postural dizziness problems with feet and/or shoes, use of psychoactive medications, and home hazards.[466]

Intrinsic Risk Factors	Extrinsic Risk Factors
Advanced age	Lack of stair handrails
Previous falls	Poor stair design
Muscle weakness	Lack of bathroom grab bars
Gait & balance problems	Dim lighting or glare
Poor vision	Obstacles & tripping hazards
Postural hypotension	Slippery or uneven surfaces
Chronic conditions including arthritis, diabetes, stroke, Parkinson's, incontinence, dementia	Psychoactive medications
Fear of falling	Improper use of assistive device

Source: Centers for Disease Control. Risk Factors for Falls. https://www.cdc.gov/steadi/pdf/risk_factors_for_falls-a.pdf

Health Effects

Efficacy of Home Safety for Prevention of Childhood Unintentional Injury

The CDC's National Action Plan for Child Injury Prevention lists the leading causes of child injury, which include motor vehicle crashes, suffocation, drowning, poisoning, fires, and falls.[467] In the National Plan, the CDC defines injury as "the physical damage that results when a human body is suddenly subjected to energy in amounts that exceed the threshold of physiologic tolerance—or else the result of a lack of one or more vital elements, such as oxygen."[468] Unintentional injuries in the United States, as is the case in many industrialized countries, remain among the leading cause of childhood death and manifests as a health disparity demarcated by a steep social gradient in child injury mortality and morbidity".[469] Overall the national trend from 2004 to 2014, shows that the infant mortality rate decreased by 14.7%, from 6.8 to 5.8 deaths under 1 year of age per 1,000 live births, exceeding the Healthy People 2020 target.[470] Still the U.S. child (0-14 years) injury death rate (8.7 per 100,000 population) ranks among the worst of all high income countries in the world.[471] And despite declines in the overall national rates, the health disparity among racial groups persists as evidenced by the infant death rate in the United States which is still more than twice for black non-Hispanic infants than for white non-Hispanic infants (10.9 vs. 4.9 infant deaths per 1,000 live births).[472] The National Plan identifies unintentional child injuries rates of traffic-related injuries are highest for children from age 5–19 years; falls are the leading cause of nonfatal injuries, death rates for drowning exceed those from falls, fires, pedal cycle injuries, pedestrian injuries, and poisoning.

A systematic review by *Kendrick et al* reported other proxy indicators of disadvantage such as housing tenure, parental unemployment, income levels and overcrowding which have found to be associated with child injury.[473] Other important factors that are associated with greater risk for childhood injury include younger maternal age, single and step parent households, larger households with more older siblings, and lower levels of (usually maternal) education status. The *Kendrick et al* systematic review and meta-analysis, which included 98 studies, was designed to evaluate 1) the effectiveness of home safety education in reducing child injury rates or increasing practices aimed at preventing childhood injuries in the home and 2) evaluate the effect of home safety interventions by social group. The findings represent the best available evidence on the efficacy of delivering home safety interventions to increase home safety, reduce childhood injuries and address inequalities.

The findings draw conclusions from two separate analyses designed to determine efficacy of reducing child injury rates: analyses were unadjusted (Analysis 1.1) and adjusted (Analysis 1.2) for baseline injury rates in controlled before and after (CBA) studies. Based on results in Analysis 1.1 the authors found that efficacy of all types of home safety interventions did not appear to be associated with a reduction in injury rates (IRR 0.93, 95% CI 0.83 to 1.05) and there was significant heterogeneity between effect sizes. However, the heterogeneity may be partly explained by the setting in which the intervention was delivered, with possible evidence of a greater effect in those delivered in the home (clinical setting IRR 1.07, 95% CI 0.99 to 1.17; home settings IRR 0.83, 95% CI 0.68 to 1.01; community IRR 1.03, 95% CI 0.69 to 1.54), and yet no significant heterogeneity between effect sizes in any of these subgroup analyses.

Findings from the analysis that adjusted for baseline injury rates led the authors to determine that "home safety interventions most commonly provided as home-based one-to-one, face-to-face education, especially with the provision of safety equipment, are effective in increasing a range of safety practices". Based on results in Analysis 1.2 authors also found some evidence that such interventions may reduce injury rates, particularly where interventions are provided at home and targeted to those at greater risk for unintentional injuries from falls. In this adjusted analysis the authors found home safety interventions may be associated with a reduction in injury rates (IRR 0.89, 95% CI 0.78 to 1.01) and though there was significant heterogeneity between effect sizes, yet no significant heterogeneity between effect sizes in the subgroup analyses. In the adjusted analyses the heterogeneity of effects may be partly explained by the setting in which the intervention was delivered with a significant effect found for interventions delivered in the home (IRR 0.75, 95% CI 0.62 to 0.91) compared to those delivered in clinical settings (IRR 1.07, 95% CI 0.99 to 1.17) or within the community (IRR 0.77, 95% CI 0.52 to 1.16).

Findings from the analysis that adjusted for baseline injury rates led the authors to determine that "home safety interventions most commonly provided as home-based one-to-one, face-to-face education, especially with the provision of safety equipment, are effective in increasing a range of safety practices".

Although there is a lack of evidence for the effectiveness of home safety interventions in reducing rates of thermal injuries or poisonings, there was some evidence that multifactorial interventions provided in the home setting may reduce rates of all injuries combined.[474] The conclusions of Kendrick et al stated "home safety interventions most commonly provided as one-to-one, face-to-face education, especially with the provision of safety equipment, are effective in increasing a range of safety practices".[475] Such home safety interventions were effective in increasing a wide range of safety practices including having a safe hot tap water temperature, a functional smoke alarm, having or practicing a fire escape plan, storing medicines and cleaning products out of reach, having syrup of ipecac and the poison control center number accessible, having a fitted stair gate, not using a baby walker and using socket covers on unused sockets. Kendrick et al also concluded that providing free, low cost or discounted safety equipment appeared to be more effective in improving some safety practices than those interventions not doing so. As for reducing the rates of injuries for children at greater risk, there was no consistent evidence that interventions were less effective in families whose children were at greater risk of injury.

Efficacy of Fall Prevention for Older Adults

A recent consensus statement among experts defines a fall as "an unexpected event in which the participant comes to rest on the ground, floor, or lower level". For older adults, which is and will be a growing demographic, deaths from falls increased from 2000 to 2008, from an age-adjusted rate of 2.6 per 100,000 in 2000 to 4.2 per 100,000 in 2008; (p<0.000). In another systematic review (Deandrea 2010) estimated 15% of falls result from an external event that would cause most people to fall, a similar proportion have a single identifiable cause such as syncope, and the remainder result from multiple interacting factors (Campbell 2006). CDC has reported for fall injuries among older adults there are an estimated 2.8 million emergency visits and over 800,000 patients a year are hospitalized because of a fall injury, most often because of a head injury or hip fracture. Research findings have also reported 20% of falls cause a serious injury such as broken bones or a head injury. Overall more than 95% of hip fractures are caused by falling , usually by falling sideways; and falls are the most common cause of traumatic brain injuries as well.

A meta-analysis and systematic review by *Gil lespie et al* found home safety assessment and modification interventions were effective in reducing rate of falls (RR 0.81, 95% CI 0.68 to 0.97; six trials; 4208 participants) and risk of falling (RR 0.88, 95% CI 0.80 to 0.96; seven trials; 4051 participants).[476] Findings from this report indicated multifactorial interventions for fall prevention in older adults that assess an individual's risk of falling, and then carry out tailored treatment plans, including home remediation, or arrange referrals to reduce the identified risks are effective at reducing unintentional injury rates. Multi-factorial interventions, which include individual risk assessment, reduced rate of falls (RaR 0.76, 95% CI 0.67 to 0.86; 19 trials; 9503 participants), but not the risk of falling (RR 0.93, 95% CI 0.86 to 1.02; 34 trials; 13,617 participants).[477]

Thus, current evidence shows that this multi-factorial type of intervention reduces the number of falls in older people living in the community but not the number of people falling during follow-up. Most importantly multi-factorial interventions provided in the home setting were found to be more effective for people at higher risk of falling. Evidence indicated that home safety interventions were more effective in reducing rate of falls in the higher risk subgroup, however the same analyses was unable to detect a significant difference in treatment effect between the subgroup's risk of falling. The evidence also suggested that home safety interventions for fall prevention targeted at participants at higher risk for unintentional injuries from falls appear to be more effective when delivered by an occupational therapist in the home setting. Therefore, Gillespie et al concluded that group and home-based exercise programs, and home safety interventions reduce rate of falls and risk of falling, while multifactorial assessment and intervention programs reduce rate of falls but not the risk of falling.[478]

Remediation

Since factors related to unintentional injuries are multiple, interdependent and complex, the best approach is a community based solution to prevention that needs to be carried out on multiple levels of the public health impact pyramid.[479] To better understand this approach *Mack et al* 2015 has adapted the Health Impact Pyramid (HIP) to differentiate between the multiple levels of interventions for older adult fall prevention. Interventions at the higher tiers have less of a population health impact and increasing individual effort, while lower tiers provide greater population impact and less individual efforts but more collective action through administrative policy changes, engineering passive prevention controls or social change. Population health interventions are multilevel if implemented at the individual, physician, clinic, health-care organization, and/or community level. Evidence increasingly shows such a multilevel approach leads to more substantial and sustained changes in behaviors in the individuals and, in turn, to better population health outcomes than single-level interventions.

The implementation of multi-factorial interventions targeted at susceptible population subgroups, such as children and older adults, experiencing health disparities is needed to address the inequalities and underlying causes of unintentional injuries through home modifications.

However, a key component to the success of a multilevel approach is active primary prevention program that provides multi-factorial interventions (Tier 3 in HIP) in the home setting which include health education, home environment assessment, and remediation or modifications tailored to provide home safety for the specific needs of different aged subgroups. The implementation of multi-factorial interventions targeted at susceptible population subgroups, such as children and older adults, experiencing health disparities is needed to address the inequalities and underlying causes of unintentional injuries through home modifications.

Child home safety programs need to provide multifaceted, multifactorial home interventions to address the known and modifiable physical hazards and social determinants of health to reduce injury rates related to the home environment. Accordingly, *Kendrick et al* noted that three separate systematic reviews found that single-level "education interventions may either not address inequalities in childhood injury or may widen existing inequalities (Kendrick 2000; Towner 2005; van Weeghal1997), which may occur either through inequalities in access to, uptake of, or differential effectiveness of interventions between social groups".[480] Likewise public health strategies targeting fall prevention in older adults are recommended to engage multiple levels of the Health Impact Pyramid at the same time in order to have the greatest impact. In fact, *Mack et al* (2015) found fall prevention strategies that have been most effective have engaged in multifaceted community based approaches that consider the multiple causative factors in falls particularly those related to individual occupants and physical features of the home environment — interventions related to Tiers 2–5 of the HIP; (Stevens, 2010).

For instance, homes can have passive prevention systems included in the building design and constructed to protect elderly occupants from fall-related injuries. At the same time policy changes such as enhancing building codes for fall prevention are also necessary to ensure the default option in design is safety for occupants of all ages. Current research shows structural modifications, such as installation of handrails, grab bars, and improved lighting are promising interventions for reducing risk of falls among older adults comes from two systematic reviews (Gillespie et al., 2012; Turner et al., 2011).[481,482] The systematic review by *Gillespie et al* 2012 identified 40 trials with multifactorial interventions- where "multifactorial interventions consist of more than one main category of intervention, but participants receive different combinations of interventions based on an individual assessment to identify potential risk factors for falling". Initial assessments were generally carried out by one or more health professionals and an intervention was then provided or recommendations given or referrals made for further action (Gillespie et al). Home environmental assessment, health education and home modification are necessary but may not be sufficient unless combined with care management (occupational therapy, prescribed multi-component exercise, clinical screening and wellness visits) and sustainable social support services.

Cost Savings

Preventable unintentional injuries, the majority of which are related to remediable housing conditions, are a public health problem that has an attainable solution. CDC has estimated that nearly $130 billion of the $671 billion in fatal injury costs were attributable to unintentional injuries.[483] The economic costs of unintentional injuries are substantial and will continue to increase without the implementation of cost-effective multilevel public health strategies. There is also evidence that substantial savings could be achieved, particularly for third-party payers such as health maintenance organizations, if such prevention strategies were promoted more effectively through the public health and clinical medicine infrastructure.[484] Targeted multifactorial interventions also have the most potential to eliminate known health disparities in society which are disproportionately affecting the most vulnerable and susceptible populations in American society- infants, toddlers and older adults. Thus, public health interventions that have the most potential for a return on investment align with subpopulation most in need in the form of disparities that manifest in avoidable emergency medical costs. However, there is limited number of economic evaluations on multifactorial interventions in the home setting and further research is needed to determine the most cost-effective programs.

Among evidence-based community fall prevention programs there are two models that demonstrated a return on investment — e.g., Moving for Better Balance (160% return) and Stepping On (100%).[485] In the HOME study, *Phelan et al* demonstrated a 70% reduction rate of modifiable medically-attended injury in the home intervention group and suggests that large-scale implementation could result in a 30% reduction in all medically-attended housing related injuries- estimated for children less than 5 at a total of 5 million annually.

Older Americans experienced 29 million falls causing seven million injuries and costing an estimated $31 billion in annual Medicare costs in 2014.

Older Americans experienced 29 million falls causing seven million injuries and costing an estimated $31 billion in annual Medicare costs in 2014.[486] As the U.S. population is aging, both the number of falls and the costs to treat fall injuries are likely to rise, and currently over 800,000 patients a year are hospitalized because of a fall injury, most often because of a broken hip or head injury and the average hospital cost for a fall injury is over $30,000.[487] In 13 studies reviewed in *Gillespie et al* (2012), where authors reported a comprehensive economic evaluation which provided an indication of value for money for the interventions being tested, there was some, although limited, evidence that fall prevention strategies can be cost-saving during the trial period, and may also be cost-effective over the participants' remaining lifetime. Of the thirteen trials that provided a comprehensive economic evaluation, three of these indicated cost savings for their interventions during the trial period: home-based exercise in over 80-year-olds, home safety assessment and modification in those with a previous fall, and one multifactorial program targeting eight specific risk factors.[488] Such economic findings indicate that, to obtain maximum value for money, effective strategies need to be targeted at susceptible subgroups of older people. Beyond the immediate direct personal and medical costs, the 20% of falls in older adults cause serious injuries such as fractures and head injuries—injuries that can restrict mobility, decrease quality of life, and increase the risk of premature death.[489]

The burden and costs for injury deaths and morbidity extend beyond immediate health consequences, as injuries have a significant impact on the well-being of Americans by contributing to premature death, years of potential life lost, disability and disability-adjusted life years lost, poor mental health, high medical costs and lost productivity.[490] CDC estimated total lifetime medical and work loss costs of $129.7 billion (2103) for unintentional injury deaths which was the fourth leading cause of death and represents 61%. Unintentional injuries accounted for $253.5 billion in lifetime costs, or about 87% of costs for hospitalized injuries.[491] CDC estimated total lifetime medical and work loss costs of $129.7 billion (2013) for unintentional injury deaths which was the fourth leading cause of death and represents 61% of the overall costs of fatal injuries. For all ED-treated non-fatal injuries, CDC estimated the total costs were $456.9 billion; 63% of these costs were for hospitalized injuries, for which the total estimated lifetime medical and work-loss costs were $289.7 billion.[492]

Fire Safety

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization Repair faulty wiring Installing smoke detectors	**Reduced Environmental Toxins** Reduced fire hazards in the home	**Lower Incidence of** Fire-related injuries Fire-related hospital admissions Fire-related deaths	**Unintentional Injury Prevention IVP-28** Reduce residential fire deaths	**Neighborhood & Built Environment** Quality of housing Environmental conditions

Hazard Identification

According to the *National Safety Council*, residential injuries account for thousands of deaths and hospitalizations annually.[493] Faulty electrical wiring, old and defective appliances, overloaded circuits, malfunctioning heating systems (i.e. furnaces, chimneys, electrical distribution, etc.) and lighting equipment commonly cause residential fires.[494,495] Substandard housing with these fire hazards is common in low-income communities, and increases risk of fire related injuries within the neighborhood.[496] Many subgroups, including children aged 4 years and younger, older adults, those living in poverty, people with hearing, vision, or other physical or mental limitations or disabilities, and smokers, are at heightened risk for fire related injuries.[497] In addition, households with income below the poverty level, with low levels of education attainment, and those with older or no children were less likely to have a smoke alarm, increasing their vulnerability to fire incidents.[498]

Health Impacts

Home fire safety and protection is an important health and safety issue. Between 2011 and 2013, 372,900 residential fires were reported to U.S. fire departments annually, and are estimated to cause 2,530 deaths, over 13,000 injuries, and approximately $7 billion in property damage.[499] Fire-related injuries and deaths are often caused by smoke or toxic gas inhalation.[500] Fire injury hazards are typically attributed to a lack of functional smoke alarms in key locations, and a lack of escape routes.[501,502]

Health Savings

Economic evidence surrounding injury prevention interventions, specifically in regards to fire safety, is sparse.[503] A cost effectiveness analysis of a smoke alarm giveaway program in Oklahoma City compared the program's costs with total costs of medical treatment and averted productivity losses over a five-year period. The program also included fire prevention education and battery replacement efforts. The analysis estimated that the program prevented 20 fatal and 24 nonfatal injuries. The societal discounted cost of the program was $531K, which included discounted net savings of $15 million. The health care system's total discounted net savings were nearly $1 million.

Even a scaled down version still produced a net savings. The study concluded that the program was cost effective and a good investment if implemented elsewhere.[504]

Community based programs that focus on the installation of smoke alarms, in combination with education in high-risk homes appear most effective in recognizing fire hazards and promoting fire safety.[505,506] In addition, an effective home risk assessment prior to providing education is critical. A focus on affecting building codes and legislation in regards to fire hazards could also be an effective means for addressing fire safety. There is little data on the assistance needed to implement smoke alarm promotion and intervention programs.[507] *Gielen et al.* recommends that community health workers and community partnerships be utilized to help make fire safety programs more effective and more widely implemented.[508] In addition, more research and cost benefit analysis is needed to fully assess the effectiveness of fire safety programs.

Remediation

Weatherization Repairs and Smoke Alarm Installation

Weatherization interventions routinely address fire hazards when work crews replace furnaces, clean, dry vents and repair faulty wiring. Work crews install smoke detectors if existing detectors are inoperable or missing. A systematic review of safety and injury orientated housing interventions found that homes with working smoke alarms have a 40-50% lower death rate than homes without working smoke alarms.[509,510] Another study found that 70% of deaths related to home fires occurred in homes without functional smoke alarms.[511]

A systematic review of safety and injury orientated housing interventions found that homes with working smoke alarms have a 40-50% lower death rate than homes without working smoke alarms.

Deave, et al. explored thermal injury prevention practices among parents with children (under age 4) in disadvantaged areas.[512] They found that most families had at least one working smoke alarm, but many did not have fire escape plans or fire prevention strategies, and engaged in other dangerous practices, such as unsafe matches/lighters storage, and leaving hair straighteners to cool. The study concluded that a reappraisal of health promotion messages is necessary, especially in light of new household consumables.[513]

Fire Safety Education

A 2011 report suggested that fire safety education is similarly, if not equally, effective at preventing injuries from residential fires as smoke alarm interventions. *Charters* identified the initial fire risk assessment from a trained fire educator as critical to developing a foundation for effective fire safety measures, especially among populations with high risk for fire-related injuries.[514] These interventions included providing information on maintaining smoke alarms and developing detailed fire escape plans. *Cooper et al.* evaluated different interventions' ability to increase functioning smoke alarms prevalence in households with children.[516] *Cooper et al.* found that smoke alarm promotion programs were most effective when combined with a home inspection, fire safety education, and ionization alarms with lithium batteries.[517] Fire safety education programs are equally beneficial to older residents.[518]

Lead-Based Paint/Lead-Safe Weatherization Practices

Hazard Identification

Lead toxicity presents serious health issues to humans. Major lead exposure sources include (but are not limited to) paints, water, food, dust, soil, kitchen utensils, and leaded gasoline.[519] Research has shown that lead-based paint hazards (often found in older housing) and the soil/dust it generates are the most common method of lead exposure in children.[520] The Centers for Disease Control and Prevention defines elevated blood lead levels as ≥5 micrograms of lead per deciliter of blood (μg/dL).[521] Although the Consumer Product Safety commission banned the use of lead-based paint in 1978, approximately 25% of U.S. houses (24 million housing units) have significant lead-based paint hazards such as deteriorated paint, lead dust, or bare soil lead.

Although the CDC defines an elevated blood level as ≥5μg/dL, there is no safe blood lead level for children.

LEAD-BASED PAINT/LEAD-SAFE WEATHERIZATION PRACTICES

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Lead Abatement Encapsulation (covering lead paints with a neutral paint barrier), Enclosure (covering paint with a rigid barrier) Window replacement and/or window treatments **Healthy Homes** Education on lead safety practices maintenance and repair protocols	**Reduced Environmental Toxins** Lower levels of lead dust and/or chips found in the home	**Lower Incidence of:** Childhood lead poisoning	**EH-8** Reduce the blood lead levels in children **EH-17** Increase the proportion of persons living in pre-1978 housing that has been tested for the presence of lead-based paint or related hazards **EH-18** Reduce the number of U.S. homes that are found to have lead-based paint **EH-20.3** Reduce exposure to lead in the population	**Neighborhood & Built Environment** Quality of housing Environmental conditions Crime and violence **Education:** Early childhood education and development School attendence

Health Effects

Physiological Effects of Lead Exposure/Poisoning

Lead is highly toxic to humans. The most common mechanism of lead poisoning in children is ingestion. For adults, inhalation while working with lead-containing materials, is the most common mechanism of poisoning.[522] Lead can also enter the human body through the skin.[523] Notably, non-childbearing adults absorb only 10-15% of the ingested quantity while young children, infants, and pregnant women will absorb approximately 50% of the ingested quantity.[524] Thus young children, infants, and pregnant women are at a higher risk for lead poisoning. Although the CDC defines an elevated blood level as ≥5 μg/dL, there is no safe blood lead level for children.[525]

Lead has severe harmful effects to the hemopoitic (formation and development of blood cells), nervous, reproductive and the kidney systems (urinary tract).[526] Some general symptoms of lead poisoning include hypo-chromic anemia, headaches, poor attention span, irritability, loss of memory, dullness, and encephalopathy.

Health effects for different age groups vary, as the absorption percentages also vary. For example, lead poisoning in children often results in "hyperactivity, anorexia, decreased play activity, low intelligence quotient, and poor school performance."[527] Children with blood lead levels averaging 20 μg/dL, lose about 2-3 IQ points.[528] The National Research Council has reviewed numerous recent studies that reveal an association between blood lead levels and intellectual functioning. For a population that had blood lead levels greater than 30 μg/dL, the percentage of children with severe deficits (IQ < 80) increased from an expected 4% to 16%.[529] Lead also has the ability to cross the placenta during pregnancy and cause intrauterine death of the fetus, premature births, low birth weights and newborn with delayed cognitive development.[530]

Exposure to lead in childhood is the most recognized housing condition linked to increased risk of learning disabilities and behavior disorders. Lead poisoning is known to cause diminished IQ, reading and writing difficulties, attention problems, and hyperactivity. Antisocial behavior and childhood lead poisoning have also been linked. Dietrich et al. sampled 195 subjects from the 1979 Cincinnati Lead Study (CLS), a 300 child cohort followed from prenatal gestation for 6 years.[531] 10 years later, *Dietrich et al.* found a correlation between childhood blood lead level and antisocial and delinquent behaviors.[532]

Remediation

In December 2010, the U.S. Department of Housing and Urban Development released the Lead-Paint Hazard Control Grant Program evaluation report.[533] Effectiveness was operationalized as a blood lead level reduction in children at four post-intervention times: 6 months, 1 year, 2 years, and 3 years.[534] The following table shows the interior strategies used as part of the lead-paint hazard control:

Children who were six to eleven months of age at pre-intervention were found to have significant increase in blood lead levels at the one year mark due to other exposures.[535] Previous studies have shown that only children with a pre-intervention blood lead level greater than 20 µg/dL show improvement with lead hazard control interventions.[536] This study, however, showed that blood lead levels declined with time and "results at each successive collection time were significantly lower than the previous time, except for the difference between the levels at two and three years."[537] Between the 1 year and 2 year post-intervention times, blood lead levels declined 8%; they declined only 3% (not statistically significant) between year 2 and year 3.[538]

Window replacement has been a key method in reducing childhood lead exposure since windows have "the highest levels of interior lead paint and dust compared to other building components."[539] In February 2012, a follow-up study evaluated the long-term effects of window replacement over the span of 12 years for homes enrolled in the HUD Lead Hazard Control Grant Program. This is the first study to examine the long-term effects of window replacement.[540] Of the 181 homes examined, most "were low-income

The following table shows the interior strategies used as part of the lead-paint hazard control:

INTERIOR STRATEGY CODE DEFINITIONS

Strategy		Definition
Interior	01	No action
	02	Cleaning, spot paint stabilization only
	03	Level 02 plus I Complete paint stabilization, floor treatments
	04	Level 03 plus I Window treatments
	05	Level 04 plusI Window replacement, wall enclosure/encapsulation
	06	All Lead-Based Paint enclosed, encapsulated, or removed (meets public housing abatement standards)
	07	All Lead-Based Paint removed

Encapsulation The application of a covering or coating that acts as a barrier between lead-based paint and the environment, the durability of which relies on adhesion and which has an expected life of at least 20 years.

Enclosure The application of rigid, durable, construction materials that are mechanically fastened to the substrate to act as a barrier between lead-based paint and the environment.

Paint stabilization The process of repainting surfaces coated with lead-based paint, which includes the proper removal of deteriorated paint and priming.

Paint removal The complete removal of lead-based paint by wet scraping, chemical stripping, or contained abrasives.

Removal/Replacement The removal/replacement of a building component that was coated with lead-based paint.

Window Treatments The process of eliminating lead-containing surfaces on windows that are subject to friction or impact through the removal of paint or enclosure of certain window components.

Source: Scott Clark, Warren Galke, Paul Succop, JoAnn Grote, Pat McLaine, Jonathan Wilson, Sherry Dixon et al. "Effects of HUD-supported lead hazard control interventions in housing on children's blood lead." Environmental research 111, no. 2 (2011): 301-311.

at 12 years, with 65% under $20,000/year, 17% from $20,000–$29,999/year, and 18% for $30,000 or more per year".[541] The homes were then categorized into one of the following, "based on how many windows had been replaced [in their homes]: all replacement, some replacement, or non-replacement." Non-replacement means that the windows were only repaired. The analysis controlled for site, housing condition, presence of other lead paint, and season.[542] Twelve years following the intervention, homes that replaced all of their windows had 41% lower interior floor dust lead and 51% lower window sill dust lead compared to homes with non-replacement.[543] Homes that replaced some of their windows had interior floor dust lead that was 28% lower and window sill dust lead that was 37% lower than non-replacement homes.[544] Although the difference is significant between the original intervention and 12 years later, it should be noted that floor dust lead loading levels eventually declined over time.[545] Observing 6 months, 1 year, 2 years, and 3 years post-intervention, the dust lead levels were significantly higher than at the 6 years and 12 years post-intervention mark.[546] Comparing the 6 years post-intervention levels and 12 years post-intervention levels, there was only a slight difference in the dust lead levels.[547]

Health Savings

Dixon et al. examined the costs and benefits of non-replacement (repair) versus replacement of leaded windows. The cost of replacing windows varied from $1953 to $4462 per unit.[548] The health benefit cost of replacing windows instead of repairing them results in reductions of childhood exposure to lead dust. Through a cost-benefit analysis, the net economic benefit of window replacement instead of window repair was between $1700 and $2000 per unit.[549] Window replacement is restricted under the WAP because the energy return on investment (ROI) is not considered significant enough. However, if the lead risk reduction benefits were included in their economic assessment, the ROI would likely meet, if not exceed, the WAP ROI baseline.

In July 2009, *Gould* published a journal article in Environmental Health Perspectives that examined the cost-benefit analysis of controlling lead paint.[550] Lead-based paint abatement "could save $11-$53 billion in immediate medical treatment and $30-$146 million in special education costs".[551] Furthermore, a reduction in the incidence rate of attention deficit/hyperactivity disorder (ADHD) related to lead paint exposure would save $267 million.[552] Thus, for every dollar spent to limit U.S. children exposure to lead paint, the net savings would be $17-$221.[553] Comparatively common childhood disease vaccinations save $5.30-$16.50 for every dollar spent on immunizations.[554] Furthermore, criminal activity linked to lead exposure cost about $1.7 billion.[555] This totals $192-$270 billion in savings.[556] Controlling lead paint in 1 million worst-case housing units would cost somewhere between $1.2 billion and $11 billion, but the benefits to be derived from this ranged from $181 billion to $269 billion.[557]

INDIRECT IMPACTS ON OCCUPANTS

RESIDENTIAL STABILITY

Residential stability, as defined as the ability and propensity of households to remain in a home for an extended period of time, is a function of satisfaction with both housing affordability and housing quality. When an individual can afford a high quality home, then that individual is more likely to be satisfied with the housing choice and, therefore, also more likely to remain in that home. However, residential instability occurs when a resident is, in one way or another, dissatisfied with their current housing situation. One study conducted in the Netherlands estimates that more than 50% of residential moves are driven by housing-related reasons,[558] while the Panel Study of Income Dynamics (PSID) study of neighborhood-level data from the U.S. Census suggests that 43% of households decide to move out of the neighborhood because they are not satisfied with current housing space, quality, costs, and/or tenure.[559]

Residential stability is defined as the ability and propensity of households to remain in a home for an extended period of time, is a function of satisfaction with both housing affordability and housing quality.

Resident dissatisfaction with housing affordability occurs when there is misalignment between what a resident is paying for housing and the value, both perceived and realized, of that investment. As a result of the Housing Crisis and the process known as filtering, the shortage in quality housing has led to an overall inflation of the pricing and perceived value of housing over time. In fact, according to the Census Bureau, in 1940 the median home value in the U.S. was $2,938; in 1980 it was $47,000; and by 2000 it was $119,600.[560] Adjusted for inflation, the median home value in 1940 in 2000 dollars would have been $30,600. That is, in 2000 dollars, the average increase in median home value between 1940 and 2000 was over $1,400 a year.[561] Unfortunately, although income and wage growth have also increased, they haven't increased at a rate high enough to keep up with housing price growth. Therefore, each year there are more homes that become unaffordable than the previous year, leading to an overall shortage of affordable housing. As a result, individuals are forced to pay more than they otherwise would have in order to afford less quality housing, leaving residents dissatisfied with the value of their investments and more likely to relocate. According to a How Housing Matters survey, about 81% of the American population believes housing affordability is a problem and among those, 16% of adults (37 million Americans) feel either somewhat stable and secure or unstable and insecure in their current housing situation.[562]

Similar to dissatisfaction with housing affordability, resident dissatisfaction with housing quality occurs when the value of the home and related services is less than what the resident believes they should get given the amount of the investment. Even though there is a relationship between the two aspects, while housing affordability is related primarily to the inputs of the satisfaction equation, housing quality is more directly focused on the outputs. When a transaction occurs, either in the sale of a home or the leasing of an apartment, there is an inherent value of goods/services that the buyer expects to receive in exchange for the resources they invest. For any amount of money invested in a home, there is usually a baseline of services and amenities that are expected in the transaction. Any amount less than this baseline would constitute lesser quality or value. There are both quantitative and qualitative characteristics that affect the value or quality attached to the home. Though the quantitative characteristics, which include location, square footage, bedrooms, etc., are significant factors in determining housing quality, they are not relevant to the argument made in this paper.

However, property management service quality, which is a qualitative or otherwise hard-to-measure characteristic, can impact a resident's perceived value of housing quality.[563] The quality of service is determined in part by the ability and willingness of the property manager to meet the needs of the tenant.[564,565] Therefore, the more that property management can meet the needs of the tenant, the higher perceived quality of the home will be and the more satisfied the tenant will be.

Weatherization and other housing upgrades directly impact housing affordability and housing quality, which are two of the primary factors that affect resident satisfaction. In a report released by the Rental Protection Agency (RPA), of the 10 most common resident complaints, 7 of them can be alleviated through comprehensive energy efficiency and healthy housing upgrades.[566] When residents are satisfied, they are more likely to remain in the home.

Residential stability is a concept that can have lasting effects on the health and well-being of individuals. There is evidence suggesting that residential stability may be protective of mental and physical health.[567] In addition, studies also show that there may be a positive correlation between residential stability and increased school attendance and improved school performance.[568] Though limited, there is also evidence that residential stability can play a role in maintaining and improving community relationships and social cohesion.[569] Residential stability can also provide benefits to property owners and managers, but these will be discussed in the later section on Owner Non-Energy benefits.

MENTAL HEALTH

Home Intervention	Output	Outcome	Healthy People 2020 Indicator	Social Determinants of Health
Weatherization **Energy Efficiency Intervention** **Healthy Homes**	Lower utility cost Lower out of pocket medical costs Avoided injury and illness Reduce pest infestations Increased thermal comfort Reduce ambient noise Improved moisture control	Lower health related work and school absences Reduce energy cost Reduce reliance on energy assistance programs Reduce risk of eviction Reduce economic stress induced anxiety and depression Reduce healthcare induced anxiety and depression Personal income/savings Increased asthma trigger control	Mental Health and Mental Disorders - 4.1 Reduce the proportion of adolescents aged 12 to 17 years who experience major depressive episodes (MDEs). **Mental Health and Mental Disorders - 4.2** Reduce the proportion of adolescents aged 12 to 17 years who experience major depressive episodes (MDEs).	**Neighborhood & Built Environment** Quality of housing Environmental conditions Crime and violence **Economic Stability** Poverty Housing stability **Social & Community Context** Social cohesion

Although there are studies investigating the relationship between weatherization and energy efficiency retrofits, and health, the emphasis has been on physical health, with only a handful of studies assessing the effect on mental health. The majority of housing mental health studies have examined the relationship between housing stability and the mental health among the homeless population. The dearth in available studies can be attributed to the fact that mental health improvements can take years to manifest post-intervention, and because mental health assessment is labor intensive and frequently requires a professional. The following section constitutes as a cursory review of the most prominent mental health issues associated with poor housing, which can be treated with weatherization interventions and energy efficiency retrofits.

Mental Health Hazard Identification

Stress and Anxiety

Living in substandard housing and suffering the related economic burdens can severely impact mental and physical health residents. Living in unsanitary or moldy environments, without any immediate recourse, can leave residents stressed and agitated. This stress can contribute to sleeplessness, irritability and other general health conditions. Stress in turn can exacerbate asthma symptoms experienced by children. Asthma is regulated through an immune phenomenon, involving the release of hormones and neuropeptides.[570] Similar hormones and neuropeptides are released into the blood stream when an individual is stressed, which leads to hyper-responsiveness to asthma triggers and disruption to the body's regulatory system.[571]

Non-asthmatic residents can also have housing related stress. Caregivers of an asthmatic child often have to miss work in order to care for their child and forego much needed wages. This added economic burden can contribute to their own stress and negatively affect the parent-child relationship.[572] The combination of economic burdens, caregiver relationship strain, poor mental health and family hardship can lead children to suffer from the condition, toxic stress. The Center on the Developing Child at Harvard University defines toxic stress as strong, frequent, and/or prolonged adversity without adequate caregiver. Sustaining the stress response system for prolonged periods can impair brain development in child and increase their risk for stress-related health issues into adulthood.[573]

The combination of economic burdens, caregiver relationship strain, poor mental health and family hardship can lead children to suffer from the condition, toxic stress. The Center on the Developing Child at Harvard University defines toxic stress as strong, frequent, and/ or prolonged adversity without adequate caregiver support.

Residents in poor quality housing, in addition to stress, also frequently suffer from anxiety. A study, evaluating the physical and mental health in two Chicago public housing developments, found that roughly 32% of residents suffered from anxiety in the last 12 months.[574] Anxiety can stem from neighborhood problems, such as the crime rate, but the housing environment can also be a contributing factor. In the same study, 60% described their housing condition as fair or poor, with 57% of one site's resident reporting mold problems and 65% reporting cockroach infestation.[575] Consequently, caregiver stress and anxiety, and child toxic stress can be characterized as an additional household pollutant affecting resident's health.[576]

Learning and Behavioral Disorders

In addition to lead poisoning, overall housing quality can impact a child's socio-emotional health. Gifford evaluated 95 Canadian public school children aged 9-12, administering the Child Behavioral Questionnaire (CBQ) to each child's parent and teacher.[577] Each child's home condition was professionally assessed and rated. Results revealed that a child's behavior was significantly correlated with the condition of the kitchen, their bedroom, the main bedroom, the neighborhood, and the entire home.[578] Specifically, higher scores on the homes assessment, which corresponded to poorer quality, were correlated with parents reporting more behavioral problems. The study concedes that this analysis cannot conclude a causal relationship between housing quality and behavioral problems, but notes that housing quality did account for 12.7% of the variance in the behavior problems of children.

Depression

Depression is a debilitating condition that can leave sufferers feeling helpless and isolated. Populations with lower socioeconomic status are at higher risk for developing depressive symptoms due to frequent economic hardships they face.[579] Individuals living in substandard housing are at increased risk due to the added health hazard their housing confers, especially if residents feel powerless to improve their environment. The Chicago public housing study found 18% of residents were depressed according to the Composite International Diagnostic Interview.[580] Additionally the results showed that persons living in poorly built indoor and outdoor environments were 29%–58% more likely to report depression in the past six month and 36%–64% more likely to report lifetime depression than persons living in better built environments.[581]

Housing Interventions and Mental Health Benefits

Although weatherization interventions aim to alleviate the economic and health burdens that substandard housing cause, the above examples highlight its potential to address related mental health issues. Most housing program evaluations only provide a cursory review of the mental health benefits. A 2010 report reviewed 5 recent housing intervention research evaluations that measured mental health post-interventions aimed at reducing fuel poverty.[582] An intervention conducted in England and Wales found that after households received the intervention (installing better heating and insulation) adult participants self-reported lower rates of depression and anxiety.[583] Similarly, an evaluation of a New Zealand intervention, which included home insulation and a heating package, reported recipients experienced substantial improvements in all four mental health sub-scales in the Short Form Health Survey.[584]

A UK study reported that those who characterized their home as cold or too cold to be comfortable were 75% more likely to be diagnosed as with stress.[585] After the central heating and building insulation was upgraded, researchers observed a 40% reduction in mental stress. The final results suggest that improved housing quality was associated with a 30% to 60% improvement in mental health.[586]

As stress is both an agitator and result of asthma, tackling the conditions that lead to asthma will also diminish the stress asthmatic residents and their family's experience. Furthermore, by educating the resident while assessing and correcting the structural issues that lead to mold and dampness (i.e. leaky roofs, envelope issues), holistic interventions can restore "control" to residents and reduce the stress caused by powerlessness.[587] By removing asthma triggers, asthmatic residents can better manage their asthma symptoms and reduce the related stress and anxiety.

Another study conducted for the World Health Organization (WHO) evaluated a German public housing project.[588] The intervention used energy efficiency retrofits to address insulation and heating deficits in low-income public housing. In a pre-post evaluation, WHO found depression decreased after the intervention. However, further analysis is needed to discern if depressive symptoms ended or just eased.[589]

PERFORMANCE AND PRODUCTIVITY

The pathway between comprehensive housing interventions and education was presented in Figure 1. To summarize, the direct improvements in occupant health outcomes can positively impact early childhood development, educational attainment and school attendance. In the U.S. the highest rates of chronic conditions are among school-aged children in households below the poverty line.[590] Some of the chronic conditions hinder cognitive development, while other conditions prevent children from attending school and/or impair academic performance. Comprehensive housing interventions that include weatherization and energy efficiency renovations can effectively tackle the chronic health effects associated with poor housing conditions by removing contamination point sources and discouraging unsanitary practices. The following section will review the home health hazards common in poor housing quality that can impact academic performance and caregiver productivity, and will describe how comprehensive housing interventions mitigate the hazards.

Academic Performance

Lead

Elevated lead blood levels severely impact the nervous system, kidneys and blood cell.[591] Childhood exposure is correlated with deficits in Intelligence Quotient (IQ), attention, reaction time and visual-coordination.[592] Among older children (8-17), studies show a correlation between blood lead levels, and hyperactivity and impulsivity.[593] The effects of lead poisoning leave inflicted children at a severe academic disadvantage. *Evans et al.* found that among Chicago public school children, early low level lead exposure was inversely correlated with scores on standardized reading and math test in the third grade.[594]

The effect of childhood lead exposure persists into adolescence and young adulthood. Young adults, who had medium (10-19.9ug/dL) to high (20 ug/dL<) blood lead levels during childhood, are more likely to not graduate from high school, have lower class rankings, reading and writing disabilities, and impaired motor skills.[595] Later in life exposure is still dangerous. Adult lead exposure has been linked to cardiovascular disease, cognitive decline and spontaneous abortion.[596]

In the US, asthma is a primary cause of school absences in the US. In 2008, asthma accounted for an estimated 10.5 million lost school days in children with an asthma attack in the previous year.

Air Pollution

Indoor air can be compromised of various compounds such as poly-cyclical aromatic hydrocarbons (PAH), hydrocarbons, aldehydes, carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxides (NOx), and particulate matter (PM). Consequently, it is hard to delineate which contaminate triggered which health effect. Regardless, studies have shown air pollution negatively effects children's performance. A Dutch study by *Wang et a*l. found that children exposed to high levels of NO_2 at home, scored lower on memory assessments but found no effect on cognitive functioning.[597] High prenatal exposure to airborne polycyclic aromatic hydro-carbons (PAH) was associated with lower cognitive scores and moderate developmental delay among African American and Dominican infants under 3 in New York.[598] *Perera et al.* suggested that childhood exposure to PAH could adversely affect language, reading and math performance later in life.[599]

Asthma and Respiratory Conditions

In the US, asthma is a primary cause of school absences in the US. In 2008, asthma accounted for an estimated 10.5 million lost school days in children with an asthma attack in the previous year.[600] Frequent school absences is detrimental to academic performance but also places the additional burden of lost wages for the child's caregiver. It is estimated that the U.S. loses $4.28 billion annually due to lost work productivity and school absenteeism.[601] Additionally, children with asthma and other respiratory conditions are frequently sleep deprived. Mild sleep deprivation among elementary-school children is associated with hyperactivity, externalizing behavior, inattentiveness, and poor academic performance.[602] If deprivation continues into adolescence, students are at greater risk for grade retention.[603]

Although the relationship between asthma and learning disorders is uncertain, Stingone and Claudio found that among New York City Public school, asthmatic students comprised 34% of children enrolled in special education programs, compared to 19% in the general school population.[604] After controlling for socioeconomic and demographic variables, results showed that asthmatic students were 60% more likely to be enrolled in special education programs compare to non-asthmatic students.[605] The authors argue that factors related to poor asthma control (i.e. increased class and school absenteeism) increase the risk of asthmatic students being placed in special education programs and therefore could be curbed through improved asthma management interventions.[606]

Other Toxins

Mold spores, dust mites, and insects and rodent infestations carry allergens that initiate sensitization. Similarly, to asthma, such allergies increase the risk of hospitalization and school/work absenteeism. Furthermore, mold, dust mites and pests have additional risks for acute or chronic cardiovascular and respiratory issues. For example, the Hantavirus cardiopulmonary syndrome (HCPS) is transmitted through rodent secretions and excretions, and when not fatal, causes lengthy hospital stays.[607] Lengthy hospitalizations result in prolonged absence from school, which jeopardizes a child's academic progress. Additionally, school absences can continue after a child is discharged, requiring caregivers to miss work.

Remediation

Ventilation

Ventilation is a proven cost effective method to improve indoor air quality. Studies investigating the effect of indoor environment improvements on performance have focused on space outside the home (i.e. school and office buildings). A Norwegian study measure student concentration and vigilance in 35 classrooms and fond that reaction times were 5.4% faster when the ventilation rate (VR) was 12L/s per person.[608] Similarly, a U.S. study found that performance on standardized tests improved with higher VR.[609] Although these studies took place outside the home, their results are still applicable to home interventions.

Ventilation also effectively controls the moisture and humidity that foster mold growth and its related health risks.[610] Furthermore ventilation can help remove common asthma triggers, helping asthmatic children manage their symptoms and reduce the number of absences they and their guardian incur. *Mendell et al.* examined 162 Californian classrooms and found that for every 1L/s per person increase above the sample average (7 L/s per person), illness absences decreased significantly ($p < .05$).[611] It is vital that the air ventilation systems are functioning correctly, as faulty cooling coils can encourage mold growth and then disseminate spore throughout the building. Furthermore, inadequate filters can allow harmful outdoor compound to enter the home.

IMPACT ON OWNERS OF MULTIFAMILY UNITS

Weatherization and energy efficiency retrofits appear to only produce benefits for building residents, and thus multifamily unit owners perceive little incentive to invest in building retrofits as they recognize no direct benefit.[612]

However weatherization renovations can elicit several direct and indirect benefits to owners and significant returns on the initial investment.

OPERATION AND MAINTENANCE COST

Multifamily unit owners are apprehensive about initiating renovations due to the large upfront cost associated with construction. Furthermore, owners may have to forgo income if residents must relocate during renovations. It is estimated to cost roughly 2.4% more to construct green affordable housing compared to conventional affordable housing, while renovation costs vary from unit to unit. [613] However owners can recuperate the added investment through operation and maintenance savings.[614] Within the small multifamily housing market, it is not unheard-of for renters to pay a flat fee (rent and a fixed utility contribution), leaving the property owner to be responsible for paying energy bill for the whole building. Basic weatherization retrofits have the potential to reduce energy consumption by up to 15%, while deeper and more extensive retrofits can reduce consumption up to 50%.[615] Such a reduction in energy consumption would substantially reduce the property's operational cost, freeing capital to be invested in other areas.

Where tenants are responsible for the energy bills, weatherproofing a property can still reduce operation and maintenance cost associated with multifamily units. Weatherization and energy retrofits address building envelope issues (i.e. leakages, poorly sealed windows) and persistent appliance problems (i.e. faulty HVACs, furnaces, wiring and stovetops), which normally require owners to correct. These issues are frequently interrelated, and therefore each issue cannot be "fixed" in isolation. Weatherization and energy efficiency retrofits address housing deficiencies holistically, thus reducing the recurring maintenance cost caused by addressing problems individually.

TENANT AND HOUSING STABILITY

Low-income families housed in multifamily units are frequently under economic stress. Each month, the average low-income family with children only has $565 left for additional expenses after paying rent.[616] Low-income families have to stretch their limited resources and often have to choose between paying rent, buying food or paying the energy bill. Soaring energy costs further stress economic resources. Once housing becomes unaffordable, families have to move and face homelessness. Increased residential mobility is a symptom of scarce affordable housing.[617] Although residential mobility has severe social and health consequences for families, it is also detrimental for multifamily unit owners. High residential mobility can lead to high property vacancies and unstable occupancy rates, which both stifle owners' income and cash flow.

Weatherization and energy efficiency interventions can increase the affordability of low-income housing, by reducing energy consumption and the subsequent energy bills.[618] Recipients of WAP service in 2008 reported having less difficulty paying household energy bills, pay for medical prescriptions post weatherization.[619] Weatherization also plays a critical role in increasing comfort levels among low-income housing residents.[620] Improved affordability and comfort both contribute to resident overall satisfaction with their housing, which leads to improved loyalty and tenure in their homes. The combination, of which, decreases resident turnover and reduces vacancy rates.

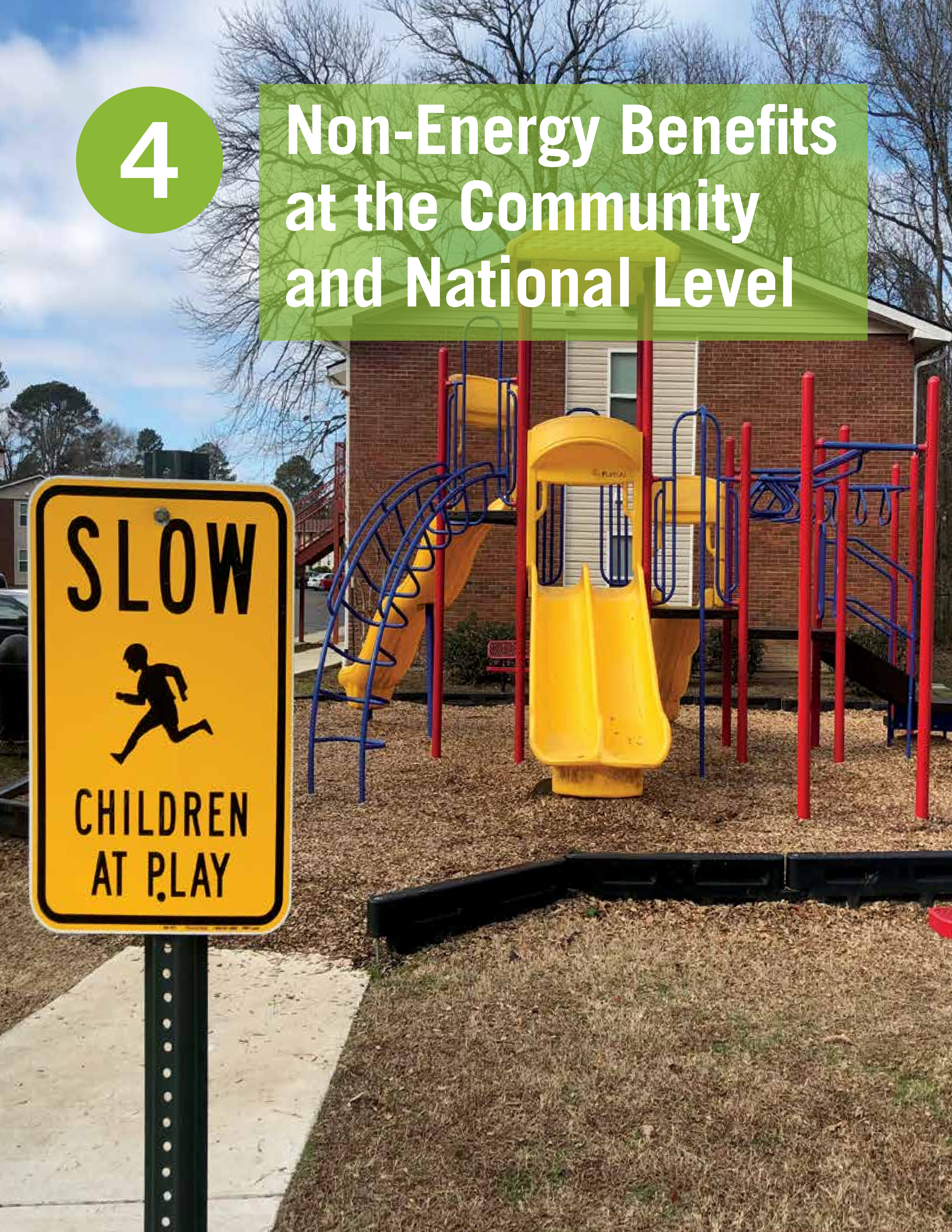
High residential mobility can lead to high property vacancies and unstable occupancy rates, which both stifle owners' income and cash flow.

ASSET VALUE

Weatherization and energy efficiency retrofits have the potential to add value to the property, especially in districts with mandated *time of lease* disclosures.[621] Time of lease disclosures require owners to provide the property's energy bill history to interested renters. As a result, a property's energy efficiency becomes a marketable characteristic and profitable advantage.

Weatherized and energy efficient properties are perceived as "future-proof"—protected against potentially costly changes in building regulation and volatile energy prices, and are thus seen as a safer investment for buyers.[622] Time of sale requirements may also abate the payback concern. Although owners understand the long term benefits of weatherized and energy efficient properties, they predict (or know) their tenure as owner is not long enough to reap the benefits.[623] Thus knowing that such renovation could add to the properties retail value could persuade owners to invest in the retrofits.[624]

4 Non-Energy Benefits at the Community and National Level



COMMUNITY LEVEL NON-ENERGY BENEFITS

COMMUNITY WELL-BEING AND NEIGHBORHOOD REVITALIZATION

Weatherization and energy efficiency measures have the capacity to improve community well-being. People that live in deprived communities are at greater risk for a wide range of poor health because they are typically of lower-socioeconomic status and are subject to a number of social, environmental, and economic stressors.[625] However, as the energy efficiency and weatherization interventions provide energy savings and non-energy benefits to individuals, the community as a dynamic system of interrelated and interconnected individuals also benefits.

The energy and healthcare savings that result from energy efficiency and weatherization measures lead to an increase in an individual's disposable income and a reduction in the amount of spending trade-offs that households experience. A 2004 study found that higher SES families spend a lower percentage of their disposable income on healthier foods.[626] As a result, communities with increasing disposable incomes due to decreasing energy and healthcare costs are less likely to experience the "Heat or Eat" trade-off and may be better equipped to make healthy food choices, leading to a healthier overall community. Many low-income areas also have less access to healthy food. This impedes neighborhood's ability to make healthy choices as research shows individuals tend to make food choices based on the food outlets available in their immediate neighborhood.[627] Areas without grocery stores or supermarkets that provide healthy food options are known as food deserts. According to a 2012 study, supermarkets and grocery stores relocated away from low-income areas due to the lack of community demand for nutritious food and the insufficient purchasing power among community members.[628] As community median income increases, food retail stores are more likely to invest in that community. The presence of a grocery store or supermarket that provides healthy food items can positively impact the health of the entire community.

People that live in deprived communities are at greater risk for a wide range of poor health because they are typically of lower-socioeconomic status and are subject to a number of social, environmental, and economic stressors.

COMMUNITY ECONOMIC GROWTH

Low-income communities can experience increased economic growth through energy efficiency and weatherization measures. Inefficient housing quality can lead to poor health outcomes and increased school absences. Studies show a negative correlation between school absences and educational achievement. An analyses of Chicago data revealed that school absenteeism is the strongest predictor of course performance and ninth grade course performance is the strongest predictor of the likelihood students would graduate.[629] Education is a major factor in escaping poverty, however, the highest prevalence of school absenteeism is found in low-income communities. A reduction in school absenteeism can increase educational achievement, which approves an individual's future employment prospects. Furthermore, educational attainment is one of the primary indicators of higher wages and lifetime economic opportunities.[630]

Weatherization and energy efficiency investment also has the potential to directly and indirectly encourage job creation. Job creation occurs primarily through the increased investment into the construction industry but also impacts the associated insurance and bank industries. Weatherization and energy efficiency retrofits and construction projects increase labor in the construction sector.[631] Additionally, indirect job creation is encouraged among periphery industries that manufacture, supply, and deliver material, fixtures or appliances need in construction.[632] This is short term job creation and will oscillate with construction sector. It is estimated that for every $1 million invested in energy efficiency development, 1.8 direct jobs and 5.1 indirect jobs are created.[633]

Weatherization and energy efficiency investment is capable of encouraging larger job creation in the long term, especially in sectors unrelated to construction. Induced job creation is the result of other industries increasing staff to serve the employees of the directly affected industries spending their extra incomes and residents or owner spending their energy bill savings. In addition to direct and indirect job creation, weatherization and energy efficiency investment is estimated to induce 4.7 jobs per $1 million investment.[634]

Communities may also indirectly experience a drop in neighborhood crime rates as a result of energy efficiency and weatherization measures. Environmental and socioeconomic stressors, and the lack of educational attainment within the community make low-income communities more susceptible to high crime rates.[635] These factors are also both the causes and effects of crime. Because energy efficient housing can relive the socioeconomic pressures of energy insecurity and eliminate the environment health hazards from homes, leading to reduced school absenteeism and improved educational attainment, crime rates are likely to dampen.

COMMUNITY RESILIENCE

Energy efficiency and weatherization measures can also increase community resilience. Studies on community resilience have defined the term, in the same way that we look at individual resilience, as the ability to recover after a traumatic event. However, a 2005 study defines community resilience as the ability to thrive despite the presence of circumstances that increase the risk of poor health and safety outcomes among community members.[636] This definition highlights the importance of resilient individuals in fostering community resilience. Resilience is "a personality characteristic that moderates the negative effects of stress and promotes adaptation."[637] The degree to which an individual is resilient has been associated with their physical well-being and educational attainment.[638] Energy efficiency and weatherization interventions have a strong correlation to improved health outcomes and furthered educational attainment, and it is likely that these interventions can also increase individual resilience and, by proxy, community resilience.

However, a 2014 study proposes that community resilience isn't just the sum of resilient individuals, but it is also determined by the quality of the built environment, the relationship between individuals in the community, and the strength of the relationship between individuals and the built environment around them.[639] There is significant research on the effects of the built environment on community resilience. The built environment refers to a community's infrastructure, which includes safe places for physical activity; the availability of affordable and nutritious food; clean air, water and soil; and the availability of safe, affordable housing.[640] These community assets are meant to be stable fixtures in the community that provide support and foster community and individual development. However, recent disasters related to extreme weather, rising sea levels, and other climate-related changes are a threat to community resiliency. Historical racial and economic segregation of the physical environment often results in a lower level of resiliency for these vulnerable populations.[641] The lack of resilience is costly, as exhibited by the dramatic increase of federal spending in response to major disasters such as Hurricane Katrina and Super Storm Sandy. The Office of Management and Budget estimates that from 2002 to 2011, the federal administration budgeted $1.9 billion per year in disaster relief funding, but spent $4.2 billion on average.[642] The prevention of failings of infrastructure systems that threaten or disrupt safe transit or delivery of utility service, such as the water crisis in Flint, Michigan, is also considered a priority for community resiliency planning.[643] Safe, affordable and energy efficient housing not only provides benefits to occupants and increased individual resilience, but also can directly and indirectly affect other aspects of community infrastructure, leading to increased community resilience.

However, a 2005 study defines community resilience as the ability to thrive despite the presence of circumstances that increase the risk of poor health and safety outcomes among community members.

SECTORAL LEVEL NON-ENERGY BENEFITS

Weatherization and energy efficiency measures are usually evaluated using the energy savings or the emission cutting paradigm.

Although both topics are valued outcomes, this narrow focus obscures the larger benefits. Weatherization and energy efficiency retrofits can bestow considerable benefit to consumers and commercial sectors. Retrofit benefits include lower maintenance and operation cost, increased worker productivity, and increased asset wealth. Furthermore, energy efficiency retrofits could also confer benefits to energy providers, such as improved provider reliability during peak demand periods.

RATEPAYER BENEFITS

The energy savings that weatherization and energy efficiency improvements produce translate into energy bill savings for the ratepayer. It is estimated that ENERGY STAR® certified homes use roughly 30% less energy compared to an uncertified home, which translates to between $200 and $400 savings each year. Another cost-benefit study revealed that LEED-certified buildings produce an average of $5.79 in energy cost savings per square foot.[645] There are also larger long term benefits to ratepayers, beyond initial energy bill savings.[646] High energy demands strain the electrical grid. In order to accommodate the demand, utility providers must build new generators to increase their distribution capacity or import energy from neighboring utility jurisdictions. The cost associated with increasing capacity is typically passed on to the ratepayer and manifests in higher energy rates. Moreover, during capacity building construction, ratepayers and residents can face outages and unreliable service.[647] Reducing end-use demand decreases grid capacity requirements, and allows utility providers and ratepayers to avoid the cost to increasing it.[648]

The California Energy Commission (CEC), operates the Public Interest Energy Research (PIER) program—an aggressive funding regime for new energy efficiency and renewable energy technologies.[649] The CEC recognizes the benefits energy efficiency and renewable energy technologies confer to ratepayers and society. In 2014, PIER funded several research and development projects to reduce this wasted lighting energy through adaptive lighting technologies—lights that adapt brightness according the room's occupancy and ambient light.[650] CEC estimated that adaptive lighting retrofits will save 86 million kWh per year and "save $10.7 million a year above amortized costs".[651] By 2020, the CEC predicts the combination of new construction according to new codes and savings due to lighting retrofits will produce $253 million net saving per year for California ratepayers (CEC, 2015).[652]

DEVELOPER BENEFITS

Despite the energy savings potential, the initial upfront cost is a barrier to weatherization and energy efficiency investment. Many developers recognize the growing trend in sustainable projects but are lukewarm toward green building projects, citing the additional cost as the main deterrent.[653] However, presumed additional costs of green project far exceed actual cost (20% vs <3.5%). Furthermore, green projects have the potential for larger returns on investments compared to similar non-green projects. A review of LEED certified buildings found that the mean internal rate of return (IRR) was 126%, while ENERGY STAR® certified homes had a mean IRR of 140%.[654] LEED and ENERGY STAR® buildings, on average, also have higher occupancy rates, which manifest as higher occupancy premiums at the point of sale. Jackson (2009) reviewed four studies and found that, after controlling for building age and other factors, occupancy premium for green building range from 4.2% to 17.9%.[655]

ENERGY PROVIDER AND INFRASTRUCTURE BENEFIT

Demand side energy efficiency developments may be perceived as counter to energy provider interests as improved efficiency would result in lower energy consumption and lower utility revenues.[656] However energy efficiency measures can reduce the cost of providing energy consistently and reliably to the public. During daily or seasonal peak demand periods the energy grid is stressed. If demand exceeds a provider's capacity, residents experience service disruptions and lengthy blackouts. As energy demand increases, energy providers are forced to expand their capacity by building new generators and improving their distribution system. By reducing demand during peak period, energy providers can avoid the associated costs to meet that capacity demand.

However, energy efficiency appliances have the potential to save consumer and the government $560 billion, producing a net savings of $300 billion.

Additional energy provider benefits stem from increased energy affordability associated with reduced demand, especially those resulting from low-income programs. Improved energy affordability reduces shuts offs and arrears suffered by low-income consumers, which also allow energy providers to avoid the operational and administrative cost associated with arrearage, bad-debt write-offs, terminations and reconnections, and customer support calls.

Currently energy efficiency programs have demonstrated their ability to reduce demand during peak periods. New York Energy $mart is the umbrella name for 40 programs targeting either business, institutional, residential, low-income, or research and development sector. Since its inception through 2004, New York Energy $mart has saved New York 1400 GWh annually.[657] Furthermore the New York program has reduced peak demand by 860MW.[658]

Supply-side energy efficiency interventions can be more cost-effective than simply constructing greater capacity.[659] Supply side interventions, which involves replacing and updating components, would drastically improve the national energy generating, transmission and distribution infrastructure.[660] Although consumers would not benefit directly from supply side interventions, in the long run such improvements could diminish future increases in energy rates.[661]

NATIONAL LEVEL NON-ENERGY BENEFITS

The majority of weatherization and energy efficiency programs are performed on individual single-family homes or multifamily units, after owners or occupants have solicited services from their local weatherization authority.

Although each program participant receives benefits separate from others, each individual benefit affects the neighborhood, the larger community and the surrounding area. Thus the aggregate of all individual benefits creates a substance national benefit. The following section covers the impact that weatherization retrofits and energy efficiency upgrades have on the job market, public energy-related spending, national energy security and the economy.

GREEN JOB CREATION

In the energy sector of the economy, green jobs are those created with the explicit purpose of reducing energy usage and lowering carbon emissions, and apply new technologies that rely on renewable sources of energy including wind, solar, geothermal and hydropower.[662] Therefore, investments in workforce training for professionals that perform efficiency assessments of housing units, weatherization or energy retrofitting services, efficiency evaluations and certifications, or similar functions are considered to support the development of the green workforce. Manufacturing of energy efficient products for the built environment is also considered part of this field.[663] Public policies for housing programs that implement efficiency standards support employment in the green energy and housing development sectors. As green energy technologies have improved and costs for energy efficient products have decreased, implementation of these such policies has become more feasible at the national level as well as for state and local jurisdictions.[664]

In 2014, *Anderson et al.* assessed the impact of energy efficiency investment in residential and commercial sector on job creation. A literature analysis revealed that initial energy efficiency investment generated between 9 and 13 gross jobs per $1million investment.[665] The

2008 WAP spent $420 million, which resulted in 8,560 full time jobs in the private sector.[666] The American Recovery and Reinvestment Act (ARRA) of 2009 significantly increased available funding by providing an additional $5 billion over three years (2010-13) for WAP. As a result, total WAP expenditure during the ARRA period supported roughly 28,000 jobs.[667]

A number of the jobs created through energy efficiency investment fall into the category of green jobs. Green jobs are defined by the Bureau of Labor Statistics as "any jobs in businesses that produce goods or services that benefit the environment or conserve natural resources" or "as jobs in which workers' duties involved making their establishment's production processes more environmentally friendly or use fewer resources." In order to be consider "green," firms have to meet one of the following five goals: (1) Energy from Renewable Sources, (2) Energy Efficiency, (3) Pollution Reduction and Removal, (4) Natural Resources Conservation, (5) Environmental Compliance, Education, and Training and Public Awareness. Examples of green jobs include building inspectors, energy auditors, insulation workers, heating/air conditioning installers, and any other jobs relating to weatherization, energy efficiency, and renewable energy investments.

FINANCIAL AND MACROECONOMIC EFFECTS

However, energy efficiency appliances have the potential to save consumer and the government $560 billion, producing a net savings of $300 billion.

Implementing weatherization and energy efficiency measures will require substantial investment from the consumer (homeowners and unit owners) and the government. Between 2010 and 2030, roughly a $259 billion investment is needed to implement energy efficient appliances alone.[668] However energy efficient appliances have the potential to save consumer and the government $560 billion, producing a net savings of $300 billion.[669] Energy efficiency appliances only represent a proportion of the total weatherization and energy efficiency measures available. The full economic impact is likely significantly larger. The impact of weatherization job creation is substantial. The 8,560 full time jobs creating by the 2008 WAP, produced $476 million in annual incomes and resulted in $1.22 billion of economic output.[670] Moreover, after WAP expenditure during the ARRA period tripled, the resulting economic output rose to $4 billion.[671]

Weatherization and energy efficiency investments' effect on job creation, energy security and government spending, when combined, would produce a positive impact on the nation's Gross National Product (GDP). Between 2000 and 2008, green construction projects alone generated $173 billion in GDP.[672] It is further predicted that energy efficiency and weatherization retrofits could generate over $477,000 in direct GDP per $1 million investment. In addition, energy efficiency and weatherization retrofits could contribute over $424,000 per $1 million indirectly to the GDP and induce over $360,000 in GDP per $1 million investment (US Green Building Council, 2008).[674]

5 Conclusion

ENERGY EFFICIENCY EVALUATION PRACTICES

The findings from this literature review support the need for a strategic policy shift in the U.S. that considers the value of health outcomes in the planning of energy policy.

There is a national need to change policies at the state and federal level to increase investments in housing programs focused on preserving low-income affordable housing units through home remediation, especially multicomponent, multifactorial programs that integrate weatherization and healthy homes services.

ENERGY EFFICIENCY EVALUATION PRACTICES

In the United States, due to the housing crisis and stagnant wages, the demand for affordable housing has outpaced availability in all counties and cities. Foreclosure rates during the Great Recession pushed former and would-be homeowners into the affordable rental housing market. The increase in demand is having a detrimental effect on low and extremely low-income households. Many are no longer able to find affordable quality housing, settling for older homes that are typically in poor condition that exposes occupants to environmental hazards with negative health effects. The energy inefficiencies common in older housing cause occupants to spend a larger proportion of their income on housing energy costs resulting in many low-income families experiencing moderate to severe housing (or rent) burden.

The analysis shows that housing affordability and quality have a significant impact on residents' physical and mental health outcomes. Poor quality housing conditions expose residents to numerous health and safety hazards that cause illness, learning disabilities and occasionally death. There are also substantial financial costs associated with each health issue, in addition to social costs. Comprehensive housing interventions –-energy efficiency measures, weatherization, and healthy homes interventions— by lowering housing related expenses and repairing structural concerns, has the potential to significantly improve housing affordability and quality. Weatherization and healthy homes measures have been shown to mitigate mold and dust related asthma exacerbations, reduce extreme temperature related deaths, and prevent childhood lead poisoning. By removing the root causes of health disparities that frequently lead to school or work absences, comprehensive housing interventions improve school attendance and work productivity. Furthermore, the stress, anxiety and depression associated with living in poor quality housing can be reduced, once housing conditions improve.

Beyond occupant benefits, owners of rental housing units can reduce operating and management costs through energy efficiency and weatherization retrofits, especially if they are responsible for the building energy costs. Energy efficiency and weatherization renovations also have the potential to increase property value as more districts are establishing time of sale or lease disclosure ordinances. Demand side energy efficiency programs reduce peak demand rates, removing the need for increasing the generation and distribution capacity, the cost of which is passed on to ratepayers. Increased investment in demand side energy efficiency and weatherization can lower government spending on energy subsidies for households and improve U.S. energy security. Furthermore, investment would stimulate job growth in the construction sectors and surrounding industries. The combined impact of job creation, increased energy security and lower government spending would have a significant positive impact on U.S. GDP.

Incorporating the non-energy benefits of these interventions into the analysis of their impact will allow policy makers to more accurately set policies and direct resources.

Findings from this research demonstrates that comprehensive housing interventions that integrate energy efficiency measures, weatherization, and healthy homes interventions not only provide a path to lower national energy costs, but also have the potential to be a source of sustainable investment in communities to replenish affordable housing and support positive economic, social and health outcomes. Incorporating the non-energy benefits of these interventions into the analysis of their impact will allow policy makers to more accurately set policies and direct resources. Over the last decade, emphasis on social determinants of health, the emergence of innovative financial models, and new policy levers and public-private partnerships have created opportunities to implement and scale up housing interventions. In order to accrue the expansive benefits conferred from those housing improvements, we encourage federal agencies, states, and local communities take advantage of all opportunities and tools available to them.

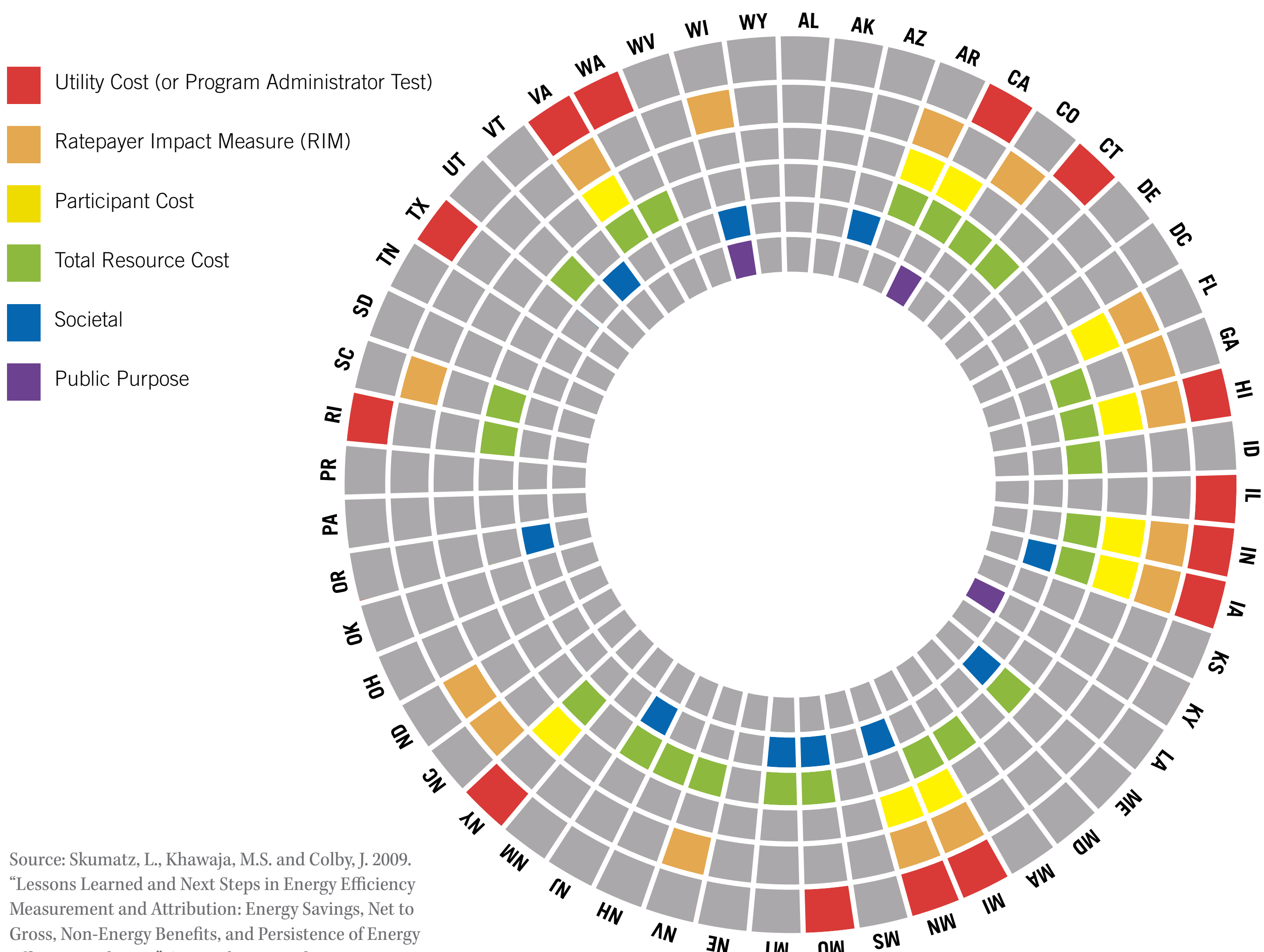
The remaining sections of the paper detail current public policies that impact administration of residential energy efficiency programs, and present policy recommendations to enhance opportunities for investments in and evaluations of such programs. An expanded understanding of occupant, owner, and societal benefits of weatherization and energy efficiency investments will improve public awareness of their value to the benefit of communities throughout the country.

ENERGY EFFICIENCY RESOURCE STANDARDS: AN OVERVIEW

Although initially aimed at saving ratepayers' money, state energy policy now targets greenhouse gas (GHG) emission, environment related health concerns and economic development. The individual policies are collectively referred to as Energy Efficiency Resource Standards (EERS).[675] As of January 2017, 26 states are currently implementing EERS policies requiring electricity savings.[676]

State legislature or the state Public Utility Commission (PUC)/Public Service Commission (PSC) frequently assign EERS compliance responsibility to Load Serving Entities (LSEs) with oversight from the PUC/PSC. Alternatively, a third party organization or the state's energy department may be assigned responsibility. Savings

SUMMARY OF BENEFIT-COST TESTS BY STATE



Source: Skumatz, L., Khawaja, M.S. and Colby, J. 2009. "Lessons Learned and Next Steps in Energy Efficiency Measurement and Attribution: Energy Savings, Net to Gross, Non-Energy Benefits, and Persistence of Energy Efficiency Behavior." CIEE Behavior and Energy Program targets can be specified in absolutes (e.g. GWh) or as percentage reduction. Furthermore, savings calculations can either include only energy savings from programs implemented that year (incremental savings) or include the years' savings generated from current and prior year's programs (annual savings). States also have a choice between setting saving targets based on the previous year's consumption (i.e. rolling basis) or based on a specific year's energy consumption (i.e. fixed basis). As there are four different forms targets can take, it is difficult to compare states performances.

PUCs/PSCs allow numerous approaches to meet EERS. Frequent measures include promoting energy efficient appliances, home weatherization, building codes, market transformation programs, and supply-side methods. Potential revenue loss is a strong disincentive for LSEs to comply with EERS. Frequently the oversight authority award energy savings-related financial incentives to encourage compliance or impose fines against LSEs that fail to meet the EERS. Occasionally, state legislatures guarantee a certain revenue amount to LSEs—known as revenue decoupling. If energy saving measures cause sale revenues to drop below a threshold without a drop in customers, the state will provide the difference.

CURRENT EVALUATION PRACTICE

An essential part of state EERS and other non-EERS state energy efficiency portfolios are the assessment of energy saving and cost effectiveness. States have developed evaluation, measurement, and verification (EM&V) procedures that vary significantly on how, and what they measure, in addition to how outcomes are used. States can choose to calculate gross energy saving, which does not consider free-ridership and spillover effects. Alternatively, states can calculate net energy savings with accounts for the rebound effect, free riders and occasionally spillover. In a 2012 survey of State ratepayer funded energy efficiency policies 12 states calculated gross energy savings, 21 calculated net savings and 9 states calculated both (n= 42).[677]

EM&V procedures differences are further illustrated in cost effectiveness analysis. Every state energy efficiency program applies a benefit cost test of which there are five options; Participant Test (PT), Utility/Program Administrator Cost Test (UCT/PACT), Ratepayer Impact Measure (RIM), Total Resource Cost Test (TRC) and Societal Cost Test (SCT).[678] Most states use multiple tests, with one designated as their primary test. TRC, which measures the net costs of a demand-side management program as a resource option based on the programs total cost, is applied the most (36 states, n=43) and also most commonly the primary test. The second most utilized test (28 states) is UCT/PACT, which calculates the net costs of a demand-side management program based on the program administrator costs (excluding any participant net costs). PT and RIM are used by 23 and 21 states respectively. The least utilized test is the SCT with 17 states. SCT is similar to TRC but considers externalities (e.g. select societal, participant and utility benefits and costs).[679]

NON-ENERGY BENEFITS

Within the basic 5 benefit cost tests there is still debate about which benefits and costs should be included in the analysis and how each should be defined.[680] One class of benefits consistently underrepresented in benefit cost analysis are participant and societal non-energy benefits (NEBs). Several non-energy benefits are included in the SCT but according to a national survey of State Energy Efficiency programs, only 12 states included customer Non-energy benefits in their primary benefit cost test. Furthermore, only 5 states included non-environmental societal benefits.[681] The majority of states that reported using non-energy benefits only explicitly included water and fuel saving, and reduced maintenance in their primary analysis. Important non-energy benefits such as health benefits, customer comfort and productivity improvements were excluded.

NEB's absence from energy efficiency evaluation is primarily attributed to being "hard to measure" (HTM) benefits. However, over the past two decades, researchers have improved the identification and measuring of non-energy benefits. Consequently, NEBs have been increasingly included in the evaluation of local and national energy efficiency programs, such as the Weatherization Assistance Program.[683] The states that account for NEBs frequently limit their analysis to easily quantifiable benefits. States also use an "adder" percentage, either alone or with measurable NEBs, to represent omitted NEBs.

Vermont's 2012's low-income retrofit program returned a benefit-cost ratio below 1.0 when assessed using TRC without NEBs. However, using total resource cost (TRC) with NEBs the benefit-cost ratio rose to over 2.0.

RATIONALE FOR INCLUDING NON-ENERGY BENEFITS IN EVALUATION

States are hesitant to include more non-energy benefits (NEBs) in benefit cost tests, citing low reliability and confidence in existing models for HTM variables. However, omitting NEBs from energy efficiency evaluation obscures and underestimates the full effect of energy efficiency programs. Vermont's 2012's low-income retrofit program returned a benefit-cost ratio below 1.0 when assessed using TRC without NEBs. However, using TRC with NEBs the benefit-cost ratio rose to over 2.0.[684] Thus by omitting NEBs from the cost effectiveness analysis, some programs may be scrapped or overlooked because they are incorrectly perceived to fall below a cost effectiveness threshold. Some states have already taken steps to expand their use of NEBs in cost effectiveness analysis. California, Vermont, Oregon, Colorado, and Massachusetts have all formally used NEBs in their regulatory assessment of programs. However, these states only include readily measurable NEBs and some only apply NEBs to a subset of programs.[685]

MEASURING NON-ENERGY BENEFITS

Utility consultants recommend using SCT as it is the more inclusive benefit-cost test. Alternatively, TRC with additional non-energy benefit analysis is recommended.[686] However before either test can be implemented, states must be able to prove the accuracy and reliability of any non-energy benefits (NEBs) measurements to be included. As previously stated, the majority of states that include NEBs in their benefit cost tests only analyze easily quantifiable benefits. Frequently states will also include a percentage adjustment or adder in lieu of HTM benefits. Vermont's Public Service Board (PSB) requires that quantifiable NEBs (water, operation and maintenance (O&M) savings, and fuel saving) be applied to applicable programs.[687] Vermont also requires a 15% NEB adder be used in cost effectiveness evaluations of energy efficient measures and low-income programs.[688]

Further research is needed to create reliable and valid methods of monetizing NEBs such as health, comfort and productivity. Steps have already been made to estimate several HTM variables. Skumatz Economic Research Associates (SERA) reviewed the values (monetary and percentage) estimated for NEBs from numerous weatherization programs, in addition to each value's size, consistency between studies and variation between programs.[689] Thereafter, SERA recommended values and adders for NEB categories since valuation methodologies had "been sufficiently documented to use with confidence in cost-effectiveness screening".[690]

After SERA's Itron study conducted additional research on behalf of the Coalition of Maryland Energy Efficiency Advocates (the Coalition). Itron recommended NEB values that Maryland should use in its cost effectiveness analysis. In July 2016, the Maryland PSC adopted "the business-as-usual value equivalents of the Itron quantified non-energy benefits for the categories of air emissions, comfort, commercial and industrial O&M, and reduced customer arrearages" (p.15).[691] Maryland also plans to incorporate additional participant, utility and societal non-energy benefits once Itron or other parties develop reliable measures.

CLEAN POWER PLAN

The 2015 Environmental Protection Agency's (EPA's) Clean Power Plan (CPP) was the first ever national standard aimed to curb power plant carbon pollution. The CPP hopes to make fossil fuel plants operate more efficiently and promote the nation's capacity for low or zero emitting power sources. Under the Clean Air Act §111(d) framework, the Clean Power Plan allows the EPA to establish interim and final carbon dioxide (CO_2) emission performance measures for two subcategories of fossil fuel electric generation units (EGUs); fossil fuel-fired electric steam generation units and natural gas-fired combined cycle generation units. Interim CO2 emission performance goals will be assessed between 2022 and 2029, while the final performances will be assessed in 2030.[692]

STATE PLANS

The Clean Power Plan provides states with guidelines for the development, submittal and implementation of EGUs performance standards and measures. However, states must ensure that the developed and implemented plans will allow their power plants individually or collectively to achieve the interim and final CO_2 performance goals. States can choose between two plan formats:

Emission standards plan– source-specific requirements ensuring all affected power plants within the state meet their required emissions performance rates or state-specific rate-based or mass-based goal.

State measures plan– includes a mixture of measures implemented by the state, such as renewable energy standards and residential energy efficiency programs that are not federally enforceable plan components. The plan can include federally enforceable source-specific requirements. The inter mixture of measures must result in meeting the state's mass-based goal. The plan must also include a backstop of federally enforceable standards on affected power plants that would be triggered if the state measures fail to result in the plants achieving the reductions on schedule. States may use the final model rule, which EPA proposed on August 3, 2016 for their backstop.[693]

States were required to submit a final plan (or an extension if required) for review by September 6, 2016. The Final complete plan must be submitted by September 6, 2018. The final rule allows 15 years for full implementation of measures, with incremental demonstrations of progress. Each state plan must include provisions that allows the state to demonstrate its progression toward the 2030 goal.

CLEAN ENERGY INCENTIVE PROGRAM

The EPA is creating a Clean Energy Incentive Program (CEIP) to reward early investment in eligible clean energy projects. States are rewarded with emission allowances or emission rate credits that are matched by the EPA based on the production of CO_2 savings through renewable energy and energy efficiency. In the CEIP proposed rule, the EPA has placed an emphasis on addressing disparities within low-income communities. Half of the allowances are available solely for projects that provide benefits to low-income communities. Furthermore, EPA has deemed that low-income community projects are eligible for twice the matching award than renewable energy projects. With these mandates, states are incentivized to encourage support for low-income community projects, of which energy efficient, affordable housing is considered an eligible project.

CURRENT STATE OF CLEAN POWER PLAN

On February 9th, 2016, the United States Supreme Court put a stay on the CPP because of legal challenges presented by the initiative. While the Supreme Court has still not issued an official ruling regarding the CPP, President Trump signed an executive order on March 28th, 2017 to roll back the CPP. On June 8th, 2017, the U.S. Environmental Protection Agency under the Trump Administration sent their CPP replacement to the Office of Management and Budget (OMB) for review. After a full review is completed by OMB, the proposed CPP replacement will be released for public comment.

POLICY RECOMMENDATIONS

Our review demonstrates that comprehensive housing interventions that integrate weatherization, energy efficiency, and healthy homes produce cost-effective benefits that mitigate environment-related health problems and enhances the well-being of low-income households.

Over the last decade, policy developments in healthcare, energy and financing have opened new avenues to investments in and increased support for such housing interventions. The following discussion outlines opportunities for funding and policy recommendations that can facilitate investment in energy efficiency in low-income multifamily housing.

Expand Allowable Weatherization Activities

There should be an increase in the number of allowable remediation activities under the Department of Energy's Weatherization Assistance Program (WAP) guidelines. Previous sections have shown the potential that weatherization and energy efficiency inventions have to mitigate the health and safety risks caused by poor housing quality. However, several potential activities are underused during WAP weatherization because the Savings to Investment Ratio (SIR) calculated for the measure is below 1.0. Window replacement is typically not allowed according to the WAP technical manual because it is not considered cost justifiable but the SIR calculations do not consider the impact that window replacement could have on preventing lead poisoning. The SIR should include the monetized health benefits of lead free window replacement, which are $6,847 in housing units built before 1940, $2,847 in units built from 1940-1960, and $632 in units built from 1960-1978 (in 2005 dollars).

The Department of Health and Human Services (HHS) should increase the amount of Low-income Heating Assistance Program (LIHEAP) funding that can be used for weatherization services from the current 15% by removing the waiver process and establishing 25% as the standard allowance for weatherization services. HHS should include the monetized health benefits of window replacement when LIHEAP programs are calculating the SIR. This change would allow more of the $3.4 Billion LIHEAP annual budget to be used proactively to improve home energy efficiency while also conducting activities such as replacing leaded windows with lead free, ENERGY STAR® windows that also address lead hazards and improve health outcomes.

Similarly, radon mitigation measures are underutilized in weatherization. The only radon mitigation measure consistently used is covering the exposed dirt in basements or crawl spaces if the households are located in high-radon zip codes. Beyond this, weatherization programs need to ensure weatherization services are preventing radon concentrations and not making them worse.[694] Improved ventilation systems reduce household radon concentration and can be cost justified if the reduction in the associated health effects (several cancers and respiratory diseases) are used in the SIR analysis.

Target Direct Energy Efficiency Investments to Low-Income and Multifamily Households

While there are programs such as LIHEAP that target low-income households, they do not address the split incentive problem.

Low-income residents that occupy multifamily homes are often the same individuals and families that are the most vulnerable to the impacts of inefficient energy infrastructure. However, due to financial and/or property management policy constraints, these households are unable to invest in energy efficient upgrades. While the property owners are able to make building-wide energy efficiency upgrades, they have no incentive to. Of the 38.6 million of the low-income households that are eligible for federal heating assistance, 79% pay their utility bills themselves.[695] Therefore, the direct reductions in utility costs from energy efficiency are accrued to the occupant and not the property owner. While there are programs such as LIHEAP that target low-income households, they do not address the split incentive problem.

There are several ways to create incentives for property owners and landlords. One way is to mandate energy efficiency upgrades for rental housing of low-income residents, where the landlord does not pay utilities. While this does target the problem of split incentives, it will likely upset property owners, who would be forced to make financial decisions that don't directly benefit them. Another way is to allocate a percentage of the utility cost benefits to go to the property manager. While it is important for property owners to benefit from energy efficiency, it is also important that the low-income residents are able to maximize their benefits as well. Therefore, designating a fair percentage that would go to the property owner is vital. The third approach used by some states has been a weatherization loan program in which the upfront capital for weatherization is paid back via additional amortized payments that are "piggybacked" on the utility bill to be paid by the low-income tenant. This program limits the financial involvement required by the property owner. However, it is important to ensure that the actual energy savings will be more than the additional loan payments that are likely to be passed on to the tenants. Another approach would be for utility companies to assign rates based on real household income plus total household expenditures. More programs are needed, similar to the ones mentioned above, that incentivize property owners and landlords to invest in energy efficiency for their low-income residents, while preserving affordable housing.

In addition to prioritizing affordable housing, state energy plans are recommended to adopt health outcome goals and scale up cost-effective integrated housing interventions as a means to improve public health and support affordable multifamily housing. Maryland's Multifamily Energy Efficiency and Housing Affordability (MEEHA)-EmPOWER program is a replicable template for states to consider. As part of the EmPOWER Maryland Energy Efficiency Act's goal of reducing energy consumption by 15% by 2015, the MEEHA-EmPOWER Program has promoted energy efficiency and affordability by directing funds to low and moderate income multifamily rental housing developments. The program is part of the State's efforts to promote energy efficiency and renewable energy sources and create and preserve affordable rental housing opportunities.

Encourage Utilities to Invest in Energy Efficiency and Weatherization Programs

States can encourage Load Serving Entities (LSEs), and energy providers to create utility sponsored energy efficiency and weatherization programs. Potential revenue loss is strong disincentive for LSEs to comply with Energy Efficiency Resource Standards (EERS). To combat the inherent disincentive states created several incentives and penalties that can still be deployed. For example, revenue decoupling allows LSEs to recoup lost revenues below a negotiated level that were due to EERS from the state. Alternatively, monetary performance bonuses, and non-compliance penalties can be applied. States that include non-energy benefits in the cost effectiveness testing could verify cashable savings from health outcomes, so the state can be more comfortable providing that match. States should use several of the compliance methods in concert to encourage utilities to invest in energy efficiency programs, as no single compliance method is as effective as a compilation of measures.

Include Affordable Housing in the State Implementation Plan for Energy

States have a range of options to reduce carbon emissions and are given considerable flexibility in the design of their implementation plans. It is therefore vital that affordability, health, and well-being are set as priorities in state energy plans to ensure there are direct energy efficiency investments in affordable housing that result in measurable benefits for occupants, owners, and low-income communities. Investing in energy efficiency and weatherization programs directed towards maintaining a national stock of affordable housing units to support low-income communities would also have a substantial effect on carbon emissions. In 2008, the WAP reduced carbon emission by over 2,246,000 metric tons, of which multifamily units contributed 310,000 metric tons. In 2010 the scaled up WAP under the Recovery Act reduced carbon emission by 7,382,000 metric tons with large multifamily units contributing 912,000 metric tons.[696] These findings prove that energy efficiency and weatherization interventions targeted at low-income communities can contribute to the states emission reduction targets and deliver a significant community benefit.

Energy Efficiency Resource Standard Guidance for States

Despite each state EERS containing similar core elements, EERS design varies significantly between states, which impedes efforts to compare state performances. The starkest differences concern which energy efficiency measures are included in state energy efficiency program, and which non-energy benefits (NEBs), if any, are included in the state's program evaluation procedures. It is vital that programs include Evaluation Monitoring &Verification procedures that accurately assess the portfolio of energy efficiency measures. Omitting NEBs analysis will cause states to underestimate the effect of potential measures, and undervalue the cost-effectiveness of energy efficiency investments that target low-and extremely low-income households – which could lead to misallocation of financial resources and states investing in less cost-effective measures.   This scenario is particularly detrimental to programs aimed at low-income households that live within multifamily housing.

The National Efficiency Screening Project (NESP) released *the National Standard Practice Manual for Assessing Cost-Effectiveness of Energy Efficiency Resources* in May of 2017. This tool is designed to standardize and upgrade the process for assessing the cost effectiveness of energy efficiency measures. The Department of Energy, the Department of Health and Human Services, and the Environmental Protection Agency should collaboratively issue guidance, to be included in this tool, on using non-energy benefits in the evaluation, measure and verification procedures. Such national direction and guidance would facilitate consistency in reporting and ensure that states implement programs that provide the maximum benefit at all levels of society.

Expand Coordination of State Energy Efficiency, Housing, Health, and Economic Development Plans and Programs

State governments play a significant role in setting priorities for housing, health, energy efficiency, and economic development services that are designed to serve low-income households, yet coordination of policies that regulate these programs is rare. However, some states have effectively streamlined public service goals and objectives to increase policy alignment. The State of New York, primarily through efforts led by the New York State Energy Research and Development Authority (NYSERDA), is a strong example of public sector collaboration that has resulted in incorporation of healthy and energy efficient housing revitalization goals in state economic development programming.[697] Because state energy policies and reduction plans can serve as a catalyst for this type of coordinated policy development, Public Service Commissions (PSCs) or Public Utility Commissions (PUCs) are positioned to be leaders in this effort in every state. PSCs and PUCs are responsible for implementing energy efficiency programs administered by utility service providers, and are responsible for setting rules and providing oversight on program efficiency targets, administrative practices, cost-benefit analyses, and other forms of program evaluation.

Therefore, PSCs or PUCs are encouraged to work with a diverse set of stakeholders, including other state housing, health and human service providers, as well as the citizens being served, to develop energy efficiency program goals and regulations. States that have aligned energy efficiency program goals with other state strategic plans for energy efficiency, health and wellness, and economic development are more likely to effectively implement efficiency program evaluation methods that capture the societal and other non-energy benefits of programs, and include comprehensive housing intervention resources that provide both affordable energy and non-energy benefits in service plans.

Therefore, PSCs or PUCs are encouraged work with a diverse set of stakeholders, including other state housing, health and human service providers, as well as the citizens being served, to develop energy efficiency program goals and regulations.

Incorporate Health Care Financing To Achieve Health Equity Based Multi-Sector Funding

Federal and private sector healthcare reform seeks to incentivize innovation in health care, reduce costs and improve population health.[698] In order to meet these aims, healthcare providers need to scale effective, evidenced-based solutions that address social determinants underlying the unequal distribution of diseases and resulting health inequities. Concurrently, the Internal Revenue Service (IRS) established new hospital community benefit policies, which have increasingly moved away from a focus on traditional charity care (financial assistance for the non-insured) toward strategies that target the social determinants of health in the wider community.[699]

This review already illustrated the impact existing comprehensive housing interventions have on the social determinants of health. The potential impact these interventions could have, if funding was increased and programs were scaled up, is substantial. The 2009 American Reinvestment and Recovery Act (ARRA) provided WAP with six times its historical funding level and also widened the eligibility criteria from 150% to 200% of the poverty level. The following 2010 program year, WAP spent $2 billon of DOE funds and weatherized 331,865 households. In total, the health and household related non-energy benefits experienced by WAP participants was valued at over $14,000 per unit.

Including energy efficiency and housing quality measures in community needs assessments, an IRS requirement for all nonprofit hospitals every three years, would increase the likelihood that hospitals include comprehensive housing interventions in their community health strategies. Community benefit investments can encompass "physical improvements and housing" and "environmental improvements." For example, Saint Joseph's Health System in Orange, CA contributed capital towards an 81-unit development for seniors.

Housing services that address environmental hazards related to health could also be covered through state Medicaid waivers. These waivers, such as Section 1115 Demonstration waivers, allow states to utilize Medicaid funds for services outside of the traditional scope. Oregon has included activities such as providing air conditioners, an energy efficiency related activity, for Medicaid recipients with respiratory ailments as part of their 1115 waiver. Michigan has been approved for a State Plan Amendment to their Medicaid program allowing for the remediation of lead-based paint hazards. With the broad health benefits that come from a comprehensive healthy homes and weatherization intervention, states may be interested in submitting waivers or amendments to their state plans to cover aspects of these services.

Medicaid managed care providers can also classify housing services as part of what is called targeted case management. Additionally, states can allow their managed care providers to enter into value-based contracts with providers, where the outcomes from housing services could be used as a payment source. For example, a Medicaid managed care organization could compensate a provider for the outcome of reducing emergency room visits following a comprehensive housing intervention. That compensation would be classified as a valid and value-based purchase by the managed care organization. Healthcare payment systems are increasingly moving away from fee for services towards value based payment arrangements and shared savings, which allow healthcare payers to more effectively fund what works.

Investment from healthcare entities such as Medicaid programs, managed care organizations, and hospitals can be braided together with other funding sources for energy efficiency and weatherization activities. For example, based on the evidence-base outlined previously in this report, analysis could be conducted by a state on the measurable health benefits from weatherization activities, and that value could be utilized to supplement the other sources of weatherization such as WAP or LIHEAP. Healthcare-related payment structures such as value-based purchasing arrangements could be utilized to turn that value into additional funds for the weatherization providers.

Partner with Mortgage Guarantors such as Fannie Mae and Freddie Mac

The 2008 Housing and Economic Recovery Act (HERA) charged Fannie Mae and Freddie Mac with a "Duty to Serve" currently underserved parts of the housing market such as manufactured housing, affordable housing preservation, and rural housing. In January of 2017, Fannie Mae and Freddie Mac were required to submit three-year plans outlining how they will assist each underserved housing market. These enterprises are primarily focused on improving affordability of housing and many of their products include the financing of energy and water efficiency measures in single- and multi-family housing. However, these enterprises should also consider financing healthy homes interventions alongside energy efficiency to maximize the energy and non-energy benefits accrued to households.

Incorporate Social Impact Financing as a Funding Source

In order for multifamily residents to receive the health and well-being related non-energy benefits, it is vital that weatherization services be included in state implementation plans. Together WAP and LIHEAP account for roughly 77% of total funding provided to state weatherization programs.[700] Despite this funding, WAP services do not reach all eligible residents. Securing private and public investment funds to scale evidence-based integrated housing interventions and environmental health services requires financial models that overcome three obstacles to realizing returns on energy efficiency investments in low-income multifamily housing; the large upfront investments, long performance period to generate savings, and savings accruing to sectors other than energy. State infrastructure banks have been created to provide long-term loans to support energy efficiency investments with long return on investment lead times, however this model often only finances projects with primarily energy savings.

Social Impact Financing (SIF), which includes social impact bonds or pay for success transactions, offers an opportunity to realize cashable savings in the form of both energy savings and lower medical costs due to the health outcomes accrued by occupants of multifamily housing. States can use SIF to attract private investors for integrated services that target health inequities in communities. Investors contribute the upfront cost for implementing evidence-based housing interventions. If the program produces the desired health and/or energy outcomes within the negotiated time frame, the state or another designated payer reimburses the investors' costs. For example, if the investor-funded housing intervention can reduce asthma-related emergency department visits or hospitalizations, then the state health provider can reimburse the investor. This kind of pay for success project overcomes the previous obstacles without putting the healthcare entity or government at financial risk.

Incentivize Private Sector Investment through Tax Credits

Low-Income Housing Tax Credits (LIHTCs) are a vital tool in affordable housing development, and should be effectively utilized to ensure affordable housing is energy efficient and as a result healthier and safer. States should ensure that projects receiving LIHTCs are in compliance with healthy housing standards and that all Qualified Allocation Plans (QAPs) specifically require the determination and elimination of health hazards and ensure best practices are used in affordable housing development. Similarly, as tax credits for homeowners performing energy efficiency improvements are developed, the analysis of the benefits of those credits should take into account the non-energy benefits from those home improvements.

Bring WAP program to HUD

The Weatherization Assistance Program (WAP) currently resides within the Department of Energy. However, the WAP program might be better suited as a Housing and Urban Development (HUD) program, because while the goal is to improve energy efficiency, the WAP program primarily supports measures that improve housing stock, both single-family and multi-family. Similar activities more broadly are conducted through programs residing at HUD, such as the Community Development Block Program. HUD also has the Office of Lead Hazard Control and Healthy Homes, which provides competitive grants to local jurisdictions for housing interventions. Adding the WAP program, which also effectively improves housing conditions, would allow for the seamless integration of funds and resources to comprehensively address poor quality and inefficient housing issues.

Appendix

SCOPE AND METHODS

METHODS

The scope of the literature review aims to comprehensively describe all of the multiple benefits related to energy efficient single- and multi-family housing. We conducted a systematic, comprehensive review of articles, published after January 1, 2000, and compiling those that mention any impacts attributable to energy efficiency and weatherization. In particular, we looked to establish a relationship between energy efficiency and the social determinants of health (SDOH). SDOH are the physical, economic and social conditions that have a significant impact on personal health and quality of life. The conceptual starting point of this research stems from on the fact that energy efficiency/weatherization interventions can adequately address many of the known physical and SDOH that are in fact the ubiquitous housing-related deficiencies found in low-income communities. We used a social ecological framework to organize our findings to account for various benefits provided different economic levels (individual-level, community-level, sectoral-level, and national-level).

Sources

Sources included peer-reviewed articles available in a comprehensive abstract title search of the Pub Med Central database as well as the Grey literature from three key federal databases (see descriptions below): EPA's HERO Database, DOE's Energy Citations Database, and HUD's Bibliographic database. Papers were either taken directly from the databases or located through Web of Science and Google School©. Criteria for inclusion in the research review papers are: the study demonstrates health and wellbeing savings, the savings are attributable to the energy efficiency and weatherization measures, and the paper was published after 2000.

Data Collection Procedures

Before database searching began, medical subject heading (MeSH) terms associated with each WAP health and safety hazard were identified. MeSH terms are the National Library of Medicine's controlled sets of naming descriptors that allows researchers to search topics by hierarchical specificity.[701] For each WAP health and safety hazard, each database was searched using MeSH terms, in addition to other relevant terms. Searches were limited to articles published after January 1st, 2000.After each search, article titles were reviewed and selected, if relevant. For every selected article, the citation was documented in an Excel spreadsheet. Furthermore, for every search command the number of articles it elicited, and the number of article selected from the search was recorded in a Word document.

Data Analysis Procedure

After the database search had concluded, the abstracts of selected articles were analyzed. Irrelevant and duplicate articles were discarded. The general narrative and hazard specific topic summaries were created from the remaining articles.

TABLE 1: MULTIPLE BENEFITS BY ECONOMIC LEVEL

		Spreading the Net: The Multiple Benefits of EE Improvements IEA	Benefits of EE in Affordable Housing EPA	Preserving Affordable Multi-Family Housing through EE
Individual	**Occupant**	Energy Savings	Reduce energy costs	Economic
		Health & Well-Being Impacts	Improve Air Quality	Health
		Health & Well-Being Impacts	Increase comfort	Comfort
		Increased disposable income	Preserve affordability	Financial Stability
		Poverty alleviation	Reduce reliance on poverty alleviation programs	Financial stability
		Poverty alleviation	Reduce risk of eviction	Financial Stability
	Owner	(Corollary of Residential Stability)	(Corollary of Residential Stability)	Decreased vacancy
			Preserve affordability	Operation Maintenance savings
			Reduce energy costs	Decreased energy bills
Sectoral	**Owner**	Increased asset values	Increased Home Value	Increased Home Value
		Industrial productivity	Demonstrate Leadership	Utility
		Energy provider and infrastructure benefits	Decreased costs	Utility
National	**Society**	Job creation	Increase job creation and market development	Economic
		Public Budgets-Reduced energy-related public expenditures		
		Energy security		
		Macroeconomic effects		
International	**Society**	Reduced GHG emissions	Reduce GHG emissions	Environmental & air quality
		Moderating energy prices		
		Natural resource management		
		Development Goals		

TABLE 2: HEALTHY PEOPLE 2020 GOALS RELATED TO MULTIPLE BENEFITS OF ENERGY EFFICIENCY AND WEATHERIZATION

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Environmental Health									
Outdoor Air Quality									
EH-3	Reduce air toxic emissions to decrease the risk of adverse health effects caused by mobile, area, and major sources of airborne toxics								
EH-3, 1	Reduce the risk of adverse health effects caused by mobile sources of airborne toxics	1,000,000	Tons	Of mobile sources of air toxic emissions	1.8M		2005	Projection/trend analysis	National emissions inventory (NEI), EPA
EH-3, 2	Reduce the risk of adverse health effects caused by area sources of airborne toxics	1,700,000	Tons	Of area sources of air toxic emissions	1.3M		2005	Modeling	NEI, EPA
EH-3, 3	Reduce the risk of adverse health effects caused by major sources of airborne toxics	700,000	Tons	Of major sources of air toxic emissions	800,000		2005	Modeling	NEI, EPA
EH-5	Reduce waterborne disease outbreaks arising from water intended for drinking among persons served by community water systems	2		Outbreaks per year	7		1999-2008	Projection/trend analysis	Waterborne Disease & Outbreak Surveillance System (WBDOSS), MMWR and CDC/NCID and State Health Departments
Toxics and Waste									
EH-8	Reduce blood lead levels in children		Ug/dL						
EH-8, 1	Eliminate elevated blood lead levels in children	0.9	percent			Of children had elevated blood lead levels in	2005-08		National Health and Nutrition Examination Survey (NHANES), CDC, NCHS

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Toxics and Waste									
EH-8, 2	Reduce the mean blood lead levels in children	1.4	Ug/dL	Average blood lead level in children aged 1 to 5 years	1.5	Average blood lead level in children aged 1 to 5 years in 2005-08	2005-2008	10% improvement	NHANES CDC, NCHS
EH-10	Reduce pesticide exposures that result in visits to a healthcare facility	10,377	Number of exposure		15,965	n/a	n/a	Modeling/ projection	National Poison Data System, American Association of Poison Control Centers
EH-11	Reduce the amount of toxic pollutants released into the environment	3.5	Billion pounds	n/a	3.9	Of toxic pollutants were released in to the environment in 2008	2008	10% improvement	U.S. National Toxics Release Inventory (TRI), EPA
Healthy Homes and Healthy Communities									
EH-13	Reduce indoor allergen levels								
EH-13, 1	Reduce indoor allergen levels: cockroaches	0.46	Units	Of cockroach allergen/gram of settled dust	0.51	Of cockroach allergen/gram of settled dust	2006	10% improvement	American Healthy Homes Survey (AHHS), HUD
EH-13, 2	Reduce indoor allergen levels: mouse	.14	Micrograms	Of mouse allergen/gram of settled dust	.16	Of mouse allergen/ gram of settled dust	2006	10% improvement	AHHS, HUD
EH-14	Increase the proportion of homes with an operating radon mitigation system for persons living in homes at risk for radon exposure	30	Percent	Of homes with radon levels of 4 pCi/L or more prior to mitigation had installed a radon mitigation system	10.2		2007	Maintain consistency with national programs, regulations, policies, and laws	Homes with Radon Mitigation Systems, Radon Vent Fan Manufacturers
EH-15	Increase the proportion of new single-family homes (SFH) constructed with radon-reducing features, especially in high-radon-potential areas	100	Percent	Of SFH homes built	28.6		2007	Maintain consistency with national programs, regulations, policies, and laws	National Builder Practices Survey, NAHB Research Center

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Healthy Homes and Healthy Communities									
EH-17	(Developmental) Increase the proportion of persons living in pre-1978 housing that has been tested for the presence of lead-based paint or related hazards								
EH-18, 1	Reduce the number of U.S. homes that are found to have lead-based paint	33,300,000	Count		37M		2005-06	10% improvement	AHHS, HUD
EH-18, 2	Reduce the number of U.S. homes that have paint-lead hazards	13,770,000	Count		15.3M		2005-06	10% improvement	AHHS, HUD
EH-18, 3	Reduce the number of U.S. homes that have dust-lead hazards	12,330,000	Count		13.7M		2005-06	10% improvement	AHHS, HUD
EH-18, 4	Reduce the number of U.S. homes that have soil-lead hazards	3,420,000	Count		3.8M		2005-06	10% improvement	AHHS, HUD
EH-19	Reduce the proportion of occupied housing units that have moderate or severe physical problems	4.2	percent	Of housing units had moderate or severe physical problems	5.2	Percent	2007	Projection/trend analysis	American Housing Survey (AHS), HUD and Census
EH-20.3	Reduce exposure to lead in the population, as measured by blood and urine concentrations of the substance or its metabolites	2.94	ug/dL	Concentration level of lead in blood samples at which 95% of the population aged 1 year and older is below the measured level	4.20	ug/dL	2003-2004	Maintain consistency with national programs, regulations, policies, and laws	NHANES, CDC/ NCHS; National Report on Human Exposure to Environmental Chemicals, CDC/ NCEH

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Cancer									
C-2	Reduce the lung cancer death rate	45.5	Deaths	Per 100,000 population	50.6	Deaths per 100,000 population	2007	10% improvement	National Vital Statistics System-Mortality (NVSS-M), CDC/NCHS; Bridged-Race Population Estimates, CDC/NCHS and Census
Heart Disease and Stroke									
HD S-2	Reduce Coronary heart disease deaths	103.4	Deaths	Per 100,000 population	129.2	Per 100,000 population	2007	Projection/trend analysis	National Vital Statistics System-Mortality (NVSS-M), CDC/NCHS; Bridged-Race Population Estimates, CDC/NCHS and Census
Injury and Violence Prevention									
Unintent. Injury Prevention									
IVP-28	Reduce residential fire deaths	0.86	People	Deaths per 100,000 population	0.96	People	2007	10% improvement	(NVSS-M), CDC/NCHS; Bridged-Race Population Estimates, CDC/NCHS and Census
Mental Health and Mental Disorders									
Mental Health Status Improvement									
MH MD-4	Reduce the proportion of persons who experience major depressive episodes (MDEs)								
MH MD-4.1	Reduce the proportion of adolescents aged 12 to 17 years who experience major depressive episodes (MDEs)	7.5	Percent	Percent of adolescents aged 12 to 17 years experienced a major depressive episodes	8.3	Percent	2008	10% improvement	National Survey on Drug Use and Health (NSDUH), SAMHSA

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Mental Health and Mental Disorders									
Mental Health Status Improvement									
MH MD-4.2	Reduce the proportion of adults aged 18 years and older who experience major depressive episodes (MDEs)	5.8	Percent	Percent of adults aged 18 years and older experienced a major depressive episode	6.5	Percent	2008		NSDUH, SAMHSA
Nutrition and Weight									
Food Insecurity									
NW S-12	Eliminate very low food security among children	0.2	Percent	POf U.S. households in December	1.3		2008	Maintain consistency with national programs, regulations, policies, and laws.	CPS-FSS, Census and USDA/ERS
NW S-13	Reduce household food insecurity and in doing so reduce hunger	6	Percent	Of U.S. households in December	14.6		2008	Retention of Healthy People 2010 target	CPS-FSS, Census and USDA/ERS
Respiratory Disease									
Asthma									
RD-1	Reduce asthma deaths								
RD-1.1	Children and adults under age 35 years	N/A	Asthma deaths		3.4	Per million children and adults under age 35 years occurred in 2007	2007	This measure is being tracked for informational purposes. If warranted, a target will be set during the decade	NVSS-M, CDC, NCHS
RD-1.2	Adults aged 35-64 years	6	Hospitalizations	per million	11	Per million adults aged 35 to 64 years occurred in 2007	2007	Projection	NVSS-M, CDC, NCH

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Asthma									
RD-2	Reduce hospitalizations for asthma								
RD-2.1	Reduce hospitalizations for asthma among children under age 5 years	18.1	Hospitalizations	per 10,000	41.4	per 10,000 children under age 5 years occurred in 2007	2007	Minimal statistical significance [1]	National Hospital Discharge Survey (NHDS), CDC, NCHS
RD-2.2	Reduce hospitalizations for asthma among children and adults aged 5 to 64	8.6	Hospitalizations	Per 10,000	11.1	per 10,000 children and adults aged 5 to 64 years occurred	2007	Minimal Statistical Significance	National Hospital Ambulatory Medical Care Survey (NHAMCS), CDC, NCHS
RD-3	Reduce emergency department (ED) visits for asthma								
RD-3.1	Reduce emergency department (ED) visits for asthma among children under age 5 years	95.5	Emergency department visits	Per 10,000	132.7	Per 10,000 children under age 5 years occurred in 2005-07	2005-2007	Minimal Statistical Significance	National Hospital Discharge Survey (NHDS), CDC, NCHS
RD-3.2	Reduce emergency department (ED) visits for asthma among children and adults aged 5 to 64 years	49.1	Emergency department visits	Per 10,000	56.4	Per 10,000 children and adults aged 5 to 64 years occurred in 2005-07	2005-2007	Minimal Statistical Significance	National Hospital Ambulatory Medical Care Survey (NHAMCS), CDC, NCHS
RD-4	Reduce activity limitations among persons with current asthma	10.2	Percent		12.7	Percent of persons with current asthma experienced activity limitations due to chronic lung and breathing problems in 2008	2008	Minimal Statistical Significance	National Hospital Ambulatory Medical Care Survey (NHAMCS), CDC, NCHS

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Asthma									
RD-5	Reduce the proportion of persons with asthma who miss school or work days								
RD-5.1	Reduce the proportion of children aged 5 to 17 years with asthma who miss school days	48.7	Percent		58.7	of children aged 5 to 17 years who had an asthma episode or attack in the past 12 months missed school days due to asthma in the past 12 months in 2008	2008	Minimal Statistical Significance	National Health Interview Survey (NHIS), CDC, NCHS
RD-5.2	Reduce the proportion of adults aged 18 to 64 years with asthma who miss work days	26.8	Percent		33.2	of adults aged 18 to 64 years who had an asthma episode or attack in the past 12 months missed work days due to asthma in the past 12 months in 2008	2008	Minimal statistical significance	National Health Interview Survey (NHIS), CDC, NCHS
RD-6	Increase the proportion of persons with current asthma who receive formal patient education	14.4	percent		12.1	of persons with current asthma received formal patient education in 2008	2008	Minimal statistical significance	National Health Interview Survey (NHIS), CDC, NCHS
RD-7	Increase the proportion of persons with current asthma who receive appropriate asthma care according to NAEPP[1] guidelines								

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Asthma									
RD-7.1	Persons with current asthma who receive written asthma management plans from their health care provider	36.8	percent		33.4	of persons with current asthma received written asthma management plans from their health care provider in 2008	2008	Minimal statistical significance	National Health Interview Survey (NHIS), CDC, NCHS
RD-7.4	Increase the proportion of persons with current asthma who do not use more than one canister of short-acting inhaled beta agonist per month	90.2	percent		87.9	of persons with current asthma did not use more than one canister of short-acting inhaled beta agonist per month in 2008	2008	Minimal statistical significance	National Health Interview Survey (NHIS), CDC, NCHS
RD-7.5	Persons with current asthma who have been advised by a health professional to change things in their home, school, and work environments to reduce exposure to irritants or	54.5	Percent		50.8	of persons with current asthma were advised by a health professional to change things in their home, school, and work environments to reduce exposure to irritants or allergens to which they are sensitive in 2008	2008	Minimal statistical significance	National Health Interview Survey (NHIS), CDC, NCHS
Social Determinate of Health									
SDOH-1	Proportion of children aged 0-17 years living with at least one parent employed year round, full time	Target: NA				Baseline: 71 percent of children ages 0-17 were living with at least one parent employed year round, full time in 2010			
SDOH-3	Proportion of persons living in poverty								

	Objective	Healthy People 2020 Target Measure	Target Data Type	Data Definition	Baseline Measure	Baseline Data Type	Baseline Year	Target Setting Method	Data source
Social Determinate of Health									
SDOH-3.1	Proportion of persons living in poverty	Not applicable	Percent	Person living below the poverty threshold	14.3	Persons living in poverty in at all ages	2010	N/A	Current Population Survey (CPS), Census and DOL/BLS
SDOH 3.2	Proportion of children aged 0-17 years living in poverty	Not applicable	Percent	Person living below the poverty threshold between ages 0-17	20.7		2010	N/A	CPS, Census and DOL/BLS
SDOH -4	Proportion of households that experience housing cost burden								
SDOH 4.1.1	Proportion of households that spend more than 30% of income on housing	Not applicable	Percent		34.6		2007	N/A	American Housing Survey (AHS), HUD and Census
SDOH-4.1.2	Proportion of households earning less than 200% of the poverty threshold that spend more than 30% of income on housing	Not applicable	Percent		20.1		2007	N/A	AHS, HUD and Census
SDOH-4.2.1	Proportion of households that spend more than 50% of income on housing	Not applicable	Percent		15.5		2007	N/A	AHS, HUD and Census
SDOH-4.2.2	Proportion of renter households that spend more than 50% of	Not applicable	Percent		7.1		2007	N/A	AHS, HUD and Census

TABLE 4: SUMMARY OF BENEFIT-COST TESTS AND POTENTIAL NEB-BASED UPDATES

Test	Benefits	Costs	States Using Traditionally	Improved treatment with NEBs
Utility Cost (for Program Administrator Test) (UCT or PAC)	Avoided supply costs for transmission, distribution, and generation (TD&G) Avoided gas and water supply costs	Program administration Participant incentives increased supply cost	CA, CT, HI, IA, IL, IN, MI, MN, MO, NY, OR, RI, TX, VA, WA, BPA	Use cost only paid by the utility
Ratepayer Impact Measure (RIM) (or No Loser's Test, or non-participants test)	Same as above plus Increased revenue	Same as above plus Decreased revenue	AR, CO, FL, GA, HI, IA, IN, MI, MN, NB, ND, NV, SC, VA, WI	
Participant Cost	Utility bill reductions Participant incentives	Participant direct costs	AR, CA, FL, HI, IA, IN, MI, MN, NY, VA	Participant NEBs
Total Resource Cost (TRC)	Avoided supply costs for TD&G Avoided gas and water supply costs Utility bill reductions	Program administration Participant incentives Participant direct costs Increases supply costs Decreased revenue	AR, CA, CT, CO, GA, HI, IA, ID, IN, MA, ME, MI, MO, MT, NH, NJ, NV, NY, RI, SC, UT, VA, WA	Include all participant and utility NEBs; (costs are already included)
Societal/Societal Cost Test (SCT)	Same as above plus Externality benefits (reduced air pollution, improved reliability, etc.)	Same as above	AZ, IA, ME, MN, MO, MT, NJ, OR, VT, WI	Include all NEBs – utility, societal, and participant NEBs valued (already generally includes all costs)
Public Purpose (PPT) (includes NEBs)	Same as above plus Participant incentives Quantifiable participant NEBs	Same as above	CA, KY, WI (low-income)	Refined metric/includes NEBs
Total Market Effects (TMET) (includes NEBs)	Same as above plus Additional participant NEBs (for program and spillover participants) Broader macroeconomic effects	Same as above	For evaluation purposes only	Refined metric/includes NEBs
Program Efficiency (PET) (includes NEBs)	Same as above	Same as above Excluding participant direct costs	For evaluation purposes only	Refined metric/includes NEBs
Initial BCA (Simple BC) (includes NEBs)	Same as Public Purpose Test plus Participant direct costs (as negative benefit)	Same as above	For evaluation purposes only	Refined metric/includes NEBs

COMMON ESTIMATION METHODS FOR NEB CATEGORIES

NEBs category	Measurement method applied
Utility Perspective	
Payment-related	
Carrying cost on arrearages	Arrearage study
Bad Debt Write-offs	Arrearage study
Reduced LI subsidy pymt/discounts	Calculated based on savings & reduced usage
Shutoffs/Reconnects	Derived from arrearage study work
Notices	Derived from arrearage study work
Customer calls/collections	Derived from arrearage study work
Service Related	
Emergency/safety	Incidence times value
Other Primary Utility	
Insurance savings	Few studies; some work from insurance tables
T&D savings (usually distrib)	Can be calc from avoided cost, line loss factors, savings
Fewer substations/infrastructure	Few studies
Power quality/reliability	Few studies
Other Primary Utility	Depends
Societal Perspective	
Economic	Third party models
Environmental/Emissions	Either generation mix & emission factors or complex models
Tax effects – unempl; tax invest. credit	Few studies; some factors available
H&S equipment/fires	Few studies
Health Care	Few studies
Social welfare indicators	Definition; few studies
Water/Wastewater infrastructure	Lack of studies
Fish/wildlife mitigation	Lack of studies
National security	Lack of studies
Other	

INTERIOR STRATEGY CODE DEFINITIONS

NEBs category	Measurement method applied
Utility Perspective	
Payment-related	
Interior	
Carrying cost on arrearages	Arrearage study
Bad Debt Write-offs	Arrearage study
Reduced LI subsidy pymt/discounts	Calculated based on savings & reduced usage
Shutoffs/Reconnects	Derived from arrearage study work
Notices	Derived from arrearage study work
Customer calls/collections	Derived from arrearage study work
Service Related	
Emergency/safety	Incidence times value
Other Primary Utility	
Insurance savings	Few studies; some work from insurance tables
T&D savings (usually distrib)	Can be calc from avoided cost, line loss factors, savings
Fewer substations/infrastructure	Few studies
Power quality/reliability	Few studies
Other Primary Utility	Depends
Societal Perspective	
Economic	Third party models
Environmental/Emissions	Either generation mix & emission factors or complex models
Tax effects – unempl; tax invest. credit	Few studies; some factors available
H&S equipment/fires	Few studies
Health Care	Few studies
Social welfare indicators	Definition; few studies
Water/Wastewater infrastructure	Lack of studies
Fish/wildlife mitigation	Lack of studies
National security	Lack of studies
Other	

Footnotes

[1] Ryan, L., Campbell, N. (2102). Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements. Retrieved from https://www.iea.org/publications/insights/insightpublications/Spreading_the_Net.pdf

[2] United States Environmental Protection Agency. (2011). Energy Efficiency in Affordable Housing: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs. *Local government climate and energy strategy series.* Retrieved from https://www.epa.gov/sites/production/files/2015-08/documents/energyefficientpurchasing.pdf

[3] Krieger, J., Higgins, D.L. (2002). Housing and Health: Time Again for Public Health Action. American Journal of Public Health, 92(5),758-768. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1447157/

[4] Olshanky, S., Passaro, D., Hershow, R., Layden, J., Carnes, B., Brody, Ludwig, D. (2005). A Potential Decline in Life Expectancy in the United States in the 21st Century." *The New England Journal of Medicine* ,352, 1138-1145. Retrieved from http://www.nejm.org/doi/full/10.1056/NEJMsr043743#t=article

[5] Mulholland, D., Rosenberg, J., Hogan, K. (2011) Assessing the Multiple Benefits of Clean Energy: A Resource for States. *Environmental Protection Agency.* Retrieved from http://epa.gov/statelocalclimate/resources/benefits.html

[6] Granade, H., Creyts, J., Derkach, A., Farese, P., Nyquist, S., Ostrowski, K. (2009). Unlocking the Energy Efficiency in the US Economy. *McKinsey & Co.* Retrieved from https://www.energystar.gov/buildings/tools-and-resources/unlocking-energy-efficiency-u-s-economy

[7] Ibid

[8] United States Environmental Protection Agency. (2011). Energy Efficiency in Affordable Housing: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs. *Local government climate and energy strategy series.* Retrieved from https://www.epa.gov/sites/production/files/2015-08/documents/energyefficientpurchasing.pdf

[9] Molina, M. (2014). The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs. *American Council for an Energy Efficient Economy*, U1402. Retrieved from https://aceee.org/research-report/u1402

[10] United States Environmental Protection Agency. (2015). State and Local Climate and Energy Program. Calculating Energy Savings. Retrieved from http://epa.gov/statelocalclimate/state/activities/measuring-savings.html

[11] Mulholland et al. *(2011)*.

[12] Ryan et al. (2012)

[13] *Ibid*.

[14] Mulholland et al. (2011).

[15] Tonn, B., Schweitzer, M. (2002). Non-energy Benefits from the Weatherization Assistance Program: A Summary of Findings from the Recent Literature. *Department of Energy Oak Ridge National Laboratories.* Retrieved from http://energyefficiencyforall.org/resources/non-energy-benefits-weatherization-assistance-program-summary-findings-recent-literature; Cluett, R., Amann, J. (2015). Multiple Benefits of Multifamily Energy Efficiency for Cost-Effectiveness Screening. *American Council for an Energy Efficient Economy*, A1502.Retrieved from https://aceee.org/multiple-benefits-multifamily-energy-efficiency; Philbrick, D., Scheu, R., Evens, A. (2014). Preserving Affordable Multifamily Housing through Energy Efficiency, Non Energy Benefits of Energy Efficiency Building Improvements. *Elevate Energy*. Retrieved from http://energyefficiencyforall.org/resources/preserving-affordable-multifamily-housing-through-energy-efficiency-non-energy-benefits

[16] Berelson, S. (2014) Myths of Low Income Energy Programs: Implication for Outreach. A*merican Council for an Energy Efficient Economy, Summer Study of Energy Efficiency in Buildings*. Retrieved from http://aceee.org/files/proceedings/2014/data/papers/7-287.pdf

[17] Ibid.

[18] Perl, L. (2013). LIHEAP: Program and Funding. *Congressional Research Service*. Retrieved from http://neada.org/wp-content/uploads/2013/08/CRSLIHEAPProgramRL318651.pdf

[19] APPRISE. (2010). LIHEAP Special Study of the 2005 Residential Energy Consumption Survey: Dimensions of Energy Insecurity for Low Income Households. *US Department of Health and Human Services, Administration for Children and Families, Office of Community Services, Division of Energy Assistance.* Retrieved from https://www.eia.gov/consumption/residential/

[20] Granade, H. et al. (2009). Unlocking Energy Efficiency in the U.S. Economy

[21] U.S. Department of Health and Human Services. (2015). Social Determinants of Health. Healthy People 2020. Retrieved from https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health

[22] Pollack, C., Egerter, S., Tabashir, S., Dekkerand, M., Braveman, P. (2008). Where We Live Matters or Our Health: The Links Between Housing and Health. *Robert Wood Johnson Foundation*. Retrieved from http://www.commissiononhealth.org/PDF/e6244e9e-f630-4285-9ad7-16016dd7e493/Issue%20Brief%202%20Sept%2008%20-%20Housing%20and%20Health.pdf

[23] Hernandez, D. (2013). Energy Insecurity: A Framework for Understanding Energy, the Built Environment, and Health Among Vulnerable Populations in the Context of Climate Change. *American Journal of Public Health*. Retrieved from http://ajph.aphapublications.org/doi/abs/10.2105/AJPH.2012.30117

[24] Beyers, M., Brown, J., Sansgook, C., Desautels, A., Gaska, K., Horsely, K.,…Anderson, S. (2008). Life and Death from Unnatural Causes Health and Social Inequity in Alameda County. *The Alameda County Public Health Department*. Retrieved from http://www.acphd.org/media/53628/unnatcs2008.pdf

[25] Ibid

[26] National Academies of Sciences, Engineering, and Medicine (2017) Communities in Action Pathways to Health Equity. Retrieved from http://www.nationalacademies.org/hmd/~/media/Files/Report%20Files/2017/Promote-Health-Equity/coh-report-highlights.pdf?utm_source=HMD+Email+List&utm_campaign=d2bc1e71c5-COH-Release-Jan-11&utm_medium=email&utm_term=0_211686812e-d2bc1e71c5-180295965&mc_cid=d2bc1e71c5&mc_eid=7a0dbc8b09

[27] Gopal K., & Siahpush, M. (2006) Widening Socioeconomic Inequalities in US Life Expectancy, 1980-2000. *International Journal of Epidemiology*, 35 (4): 969-979.Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16684899

[28] Ibid

[29] National Prevention Council. (2011) National Prevention Strategy. *U.S. Department of Health and Human Services, Office of the Surgeon General*. Retrieved from https://www.surgeongeneral.gov/priorities/prevention/strategy/report.pdf

[30] Marmot, M., Friel, S., Bell, R., Houweling, T., Taylor, S. (2008) Closing the Gap in a Generation Health Equity through Action on Social Determinants of Health. *World Health Organization*. Retrieved from http://www.who.int/social_determinants/thecommission/finalreport/en/

[31] Communities in Action Pathways to Health Equity. (2017). Retrieved from http://www.nationalacademies.org/hmd/~/media/Files/Report%20Files/2017/Promote-Health-Equity/coh-report-highlights.pdf?utm_source=HMD+Email+List&utm_campaign=d2bc1e71c5-COH-Release-Jan-11&utm_medium=email&utm_term=0_211686812e-d2bc1e71c5-180295965&mc_cid=d2bc1e71c5&mc_eid=7a0dbc8b09

[32] Krieger, N. (2001). A glossary for social epidemiology. *Journal of Epidemiology and Community Health*, 55:693-700. Retrieved from http://jech.bmj.com/content/55/10/693

[33] US EPA. (2011). Energy Efficiency in Affordable Housing: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs. Local government climate and energy strategy series. Retrieved from https://www.epa.gov/sites/production/files/2015-08/documents/energyefficientpurchasing.pdf

[34] Tonn, B., Rose, E., Hawkins, B., Conlon, B., (2014). Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. *National Evaluation of the Department of Energy's Weatherization Assistant Program*. Retrieved from http://weatherization.ornl.gov/Retrospectivepdfs/ORNL_TM-2014_345.pdf

[35] Thomson, H., Thomas, S., Sellstrom, E., Petticrew, M. (2013). Housing improvements for health and associated socio-economic outcomes. *Cochrane Database Systematic Reviews*. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD008657.pub2/pdf/

[36] Roy, J., Maynard, M., Weiss, E. (2008). The Hidden Costs of the Housing Crisis: The Long-term Impact of Housing Affordability and Quality on Young Children's Odds of Success. *Partnership for America's Economic Success*. Retrieved from http://www.pewtrusts.org/~/media/legacy/uploadedfiles/wwwpewtrustsorg/reports/partnership_for_americas_economic_success/paeshousingreportfinal1pdf.pdf

[37] Wardrip, K. (2009). Housing Affordability Trends for Working Households: Affordability Worsens Despite Decline in Home Prices. *Center for Housing Policy*. Retrieved by http://www.lhop.org/wp-content/uploads/Strategies-for-Increasing-Housing-Affordability.pdf

[38] Joint Center for Housing Studies. (2012). The State of the Nation's Housing 2012. *Joint Center for Housing Studies of Harvard University*. Retrieved from http://www.jchs.harvard.edu/research/publications/state-nation%E2%80%99s-housing-2012

[39] Joint Center for Housing Studies. (2011). The State of the Nation's Housing: 2011. President and Fellows of Harvard College. Retrieved from http://www.jchs.harvard.edu/research/publications/state-nation%E2%80%99s-housing-2011

[40] Ibid

[41] Joint Center for Housing Studies. (2011). The State of the Nation's Housing: 2011. *President and Fellows of Harvard College*. Retrieved from http://www.jchs.harvard.edu/research/publications/state-nation%E2%80%99s-housing-2011; Joint Center for Housing Studies. (2013). The US Housing Stock Ready for Renewal Improving America's Housing 2013. Retrieved from http://www.jchs.harvard.edu/sites/jchs.harvard.edu/files/harvard_jchs_remodeling_report_2013.pdf

[42] How Housing Matters Press Release. (2016). Pessimism about Prolonged Housing Affordability Crisis is On the Rise. *2016 How Housing Matters Survey Finds*. Retrieved from https://www.macfound.org/press/press-releases/pessimism-about-prolonged-affordable-housing-crisis-rise-2016-how-housing-matters-survey-finds/

[43] Ibid

[44] Eggers, F., & Moumen, M. (2011). Rental Market Dynamics: 2009-2011. *Prepared for HUD Office of Policy Development & Research*. Retrieved from https://www.huduser.gov/portal/datasets/cinch/cinch11/Rental_Mrkt_09-11.pdf

[45] Joint Center for Housing Studies. (2015). The State of the Nation's Housing 2015. *Joint Center for Housing Studies of Harvard University*. Retrieved from http://www.jchs.harvard.edu/sites/jchs.harvard.edu/files/jchs-sonhr-2015-full.pdf

[46] US Census. (2014). Selected Housing Characteristics. (2014). *US Census American Fact Finder*. Retrieved from http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_14_5YR_DP04&prodType=table

Joint Center for Housing Studies. (2014). The State of the Nation's Housing: 2014. *President and Fellows of Harvard College*. Retrieved from http://www.jchs.harvard.edu/sites/jchs.harvard.edu/files/sonhr14-color-full.pdf

[47] Joint Center for Housing Studies. (2015). American Rental Housing: Expanding Options for Diverse and Growing Demand. Joint Center for Housing Studies of Harvard University. Retrieved from http://www.jchs.harvard.edu/americas-rental-housing

[48] Jackson, K.(2017). Crabgrass Frontier: The Suburbanization of the United States. *Oxford University Press*.

[49] Aurand, A., Emmanuel, D., Yentel, D., Errico, E. (2017). The GAP: A Shortage of Affordable Homes. *National Low Income Housing Coalition*. Retrieved from http://nlihc.org/research/gap-report

[50] Bier, T. (2001). Moving Up, Filtering Down: Metropolitan Housing Dynamics and Public Policy. *The Brookings Institution Center on Urban and Metropolitan Policy*. Retrieved from https://www.brookings.edu/research/moving-up-filtering-down-metropolitan-housing-dynamics-and-public-policy/

[51] Nunn, R., & Watson, T. (2016). The Economic Security of American Households: The Evolution of Earnings and Income. *U.S. Treasury Department Office of Economic Policy, Issue One*. Retrieved from https://www.treasury.gov/resource-center/economic-policy/Documents/US%20Treasury%20Economic%20Security%20Issue%201.pdf

[52] American Housing Survey (2000-2015). *U.S. Census Bureau*. Retrieved from https://www.census.gov/programs-surveys/ahs.html

[53] Ellen, I., & Dastrup, S. (2012). Housing and the Great Recession. *The Russell Sage Foundation and the Stanford Center on Poverty and Inequality*. Retrieved from http://furmancenter.org/files/publications/HousingandtheGreatRecession.pdf

[54] Ibid

[55] Ibid

[56] Kochhar, R., Fry, R., Velasco, G., Motel, S., Taylor, P. (2011). Wealth Gap Rises to Record Highs Between Whites, Blacks, Hispanics. *Pew Research Center*. Retrieved from http://www.pewsocialtrends.org/2011/07/26/wealth-gaps-rise-to-record-highs-between-whites-blacks-hispanics/

[57] U.S. Department of Housing and Urban Development Office of Policy Development and Research. (2012). *Housing Discrimination Against Racial and Ethnic Minorities* 2012. Retrieved from https://www.huduser.gov/portal/Publications/pdf/HUD-514_HDS2012.pdf

[58] U.S. Department of Health and Human Services. (2016). 2020 Topics and Objectives-*Objectives A-Z*. Retrieved from https://www.healthypeople.gov/2020/topics-objectives

[59] *Ibid*.

[60] Frank, D., Neault, N., Skalicky, A., Cook, J., Wilson, J., Levenson.,..Meyers, F. (2006). Heat or Eat: The Low Income Home Energy Assistance Program and Nutritional and Health Risks Among Children Less Than 3 Years of Age. *Pediatrics*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17079530

[61] The Assisted Housing Initiative. (2017). Mapping America's Rental Housing Crisis. *The Urban Institute*. Retrieved from http://apps.urban.org/features/rental-housing-crisis-map/

[62] Aurand, A., Emmanuel, D., Yentel, D., Errico, E. (2017).The Gap: A Shortage of Affordable Homes. *National Low Income Housing Coalition*. Retrieved from http://nlihc.org/research/gap-report

[63] Aurand, A., et al.

[64] Joint Center for Housing Studies of Harvard University. (2015). America's Rental Housing: Expanding Options for Diverse and Growing Demand. Retrieved from http://www.jchs.harvard.edu/sites/jchs.harvard.edu/files/americas_rental_housing_2015_web.pdf

[65] Joint Center for Housing Studies of Harvard University. (2016). The State of the Nation's Housing: 2016. Retrieved from http://www.jchs.harvard.edu/research/publications/state-nations-housing-2016

[66] Fisher, W., & Sard, B., (2017). Chart Book: Federal Housing Spending Is Poorly Matched to Need. Tilt Toward Well-Off Homeowners Leaves Struggling Low-Income Renters Without Help. *Center for Budget and Policy Priorities.* Retrieved from: https://www.cbpp.org/sites/default/files/atoms/files/12-18-13hous.pdf#page=5

[67] Fisher and Sard.

[68] Fisher and Sard.

[69] Fisher, W. & Huang, C. (2013). Mortgage Interest Deduction Is Ripe for Reform. Conversion to Tax Credit Could Raise Revenue and Make Subsidy More Effective and Fairer. *Center on Budget and Policy Priorities*. Retrieved from: https://www.cbpp.org/research/mortgage-interest-deduction-is-ripe-for-reform

[70] Center on Budget Policy and Priorities. (2016). Chart Book: Cuts in Federal Assistance Have Exacerbated Families' Struggles to Afford Housing. Retrieved from: https://www.cbpp.org/research/housing/chart-book-cuts-in-federal-assistance-have-exacerbated-families-struggles-to-afford

[71] Fisher and Sard.

[72] Schwartz, A. (2006). *Housing Policy in the United States: An Introduction*. New York: Routledge.

[73] Ibid

[74] Ibid

[75] Jackson, T. (2017). Policy Basics: Federal Rental Assistance. *Center on Budget and Policy Priorities*. Retrieved from http://www.cbpp.org/research/housing/policy-basics-federal-rental-assistance

[76] Ibid

[77] Herbert, C., McCue, D., Sanchez-Moyano, R. (2013). Is Homeownership Still an Effective Means of Building Wealth for Low-income and Minority Households (Was it Ever?). *Joint Center for Housing Studies at Harvard University*. Retrieved from http://www.jchs.harvard.edu/sites/jchs.harvard.edu/files/hbtl-06.pdf

[78] Cohen, R. (2013). Rental Housing Affordability: A Review of Current Research. *The Center for Housing Policy* (2010). Retrieved from http://www.ohiohome.org/opc/RentalHousingAffordability.pdf

[79] Joint Center for Housing Studies. (2013). America's Rental Housing - Evolving Markets and Needs. *Joint Center for Housing Studies of Harvard University*. Retrieved from http://www.jchs.harvard.edu/sites/jchs.harvard.edu/files/jchs_americas_rental_housing_2013_1_0.pdf

[80] Ibid

[81] Desmond, M. (2016) *Evicted: Poverty and Profit in the American City*. New York: Random House.

[82] Bier, T. (2001). Moving Up, Filtering Down: Metropolitan Housing Dynamics and Public Policy. *The Brookings Institution Center on Urban and Metropolitan Policy*. Retrieved from https://www.brookings.edu/research/moving-up-filtering-down-metropolitan-housing-dynamics-and-public-policy/

[83] Roy, J., Maynard, M., Weiss. E. (2008). The Hidden Costs of the Housing Crisis. *The Partnership for America's Economic Success*. Retrieved from http://www.pewtrusts.org/~/media/legacy/uploadedfiles/wwwpewtrustsorg/reports/partnership_for_americas_economic_success/paeshousingreportfinal1pdf.pdf

[84] Ibid

[85] Ibid

[86] U.S. Department of Housing and Urban Development. (2015).Worst Case Housing Needs Report to Congress. Retrieved from https://www.huduser.gov/portal/publications/affhsg/wc_HsgNeeds15.html

[87] Drehobl, A. and Ross, L. (2016). Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities. *American Council for an Energy Efficient Economy*. Retrieved from http://energyefficiencyforall.org/sites/default/files/Lifting%20the%20High%20Energy%20Burden_0.pdf

[88] *Ibid*

[89] Fisher, P., Sheehan, M., Colton, R. (2016). The Home Energy Affordability Gap 2015: United States. *Sheehan & Colton Public Finance and General Economics*. Retrieved from http://www.homeenergyaffordabilitygap.com/

[90] Fisher, P., Sheehan. M., Colton, R. (2016). The Home Energy Affordability Gap 2015: United States. *Sheehan & Colton Public Finance and General Economics*. Retrieved from http://www.homeenergyaffordabilitygap.com/

[91] Ibid

[92] *Ibid*

[93] Bier, T. (2001).

[94] Ibid

[95] Schilling, F. (2009). Code Enforcement and Community Stabilization: The Forgotten First Responders to Vacant and Foreclosed Homes. *Albany Government Law Review, Vol. 2*. Retrieved from https://www.hudexchange.info/resource/85/code-enforcement-and-community-stabilization-the-forgotten-first-responders-to-vacant-and-foreclosed-homes/

[96] Bier, T. (2001).

[97] Pettit, B., & Snell, J. (2001). PA-0102: Public Housing Breaks the Mold: Part II. *Home Energy, 33-37*. Retrieved from https://buildingscience.com/documents/published-articles/pa-public-housing-breaks-mold-part-II/view

[98] Drehobl, A. and Ross, L. (2016).

[99] U.S. Environmental Protection Agency. (2011). Energy Efficiency in Affordable Housing: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs. Retrieved from https://www.epa.gov/sites/production/files/2015-08/documents/energyefficientpurchasing.pdf

[100] Harkness, J., & Newman, J. (2005). Housing Affordability and Children's Well-Being: Evidence from the National Survey of America's Families. *Harvard University Housing Policy Debate, 16; 223-55.* Retrieved from http://www.tandfonline.com/doi/abs/10.1080/10511482.2005.9521542;

Kushel, M., Gupta, R., Gee, L., Haas, J. (2006). Housing Instability and Food Insecurity as Barriers to Health Care among Low Income Americans. Journal of *General Internal Medicine, 21(1), 71-7.* Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1484604/

Cook, J., Frank, D., Casey, P., Rose-Jacobs, R., Black, M., Chilton, M., Ettinger, S., Cutts, D. (2008) A Brief indicator of Household Energy Security: Associations with Food Security, Child Health and Child Development in US Infants and Toddlers. *Pediatrics, e867-e875.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18829785;

Frank, D., Neault, N., Skalicky, A., Cook, J., Wilson, J., Levenson, S., Berkowitz, C. (2006). Heat or Eat: The Low Income Home Energy Assistance Program and Nutritional and Health Risks Among Children Less than 3 Years of Age. *Pediatrics*, e1293-e1301. Retrieved from http://pediatrics.aappublications.org/content/118/5/e1293

Hernández, D. (2013). Energy Insecurity: A Framework for Understanding Energy, the Built Environment, and Health Among Vulnerable Populations in Context of Climate Change. *American Journal of Public Health*, e1-e2. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3673265/

[101] Hernández, D. (2016). Understanding 'energy insecurity' and why it matters to health. *Social Science & Medicine*, 167, 1-10. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5114037/

[102] Drehobl, A., Ross, L. (2016). Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low-Income and Underserved Communities. *American Council for and Energy-Efficient Economy*. Retrieved from http://energyefficiencyforall.org/sites/default/files/Lifting%20the%20High%20Energy%20Burden_0.pdf

[103] Cook, J., Frank, D., Casey, P., Rose-Jacobs, R., Black, M., Chilton, M., Ettinger, S., Cutts, D. (2008) A Brief indicator of Household Energy Security: Associations with Food Security, Child Health and Child Development in US Infants and Toddlers. *Pediatrics, e867-e875.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18829785

[104] 2013 American Housing Survey. (2013) Retrieved from https://www.census.gov/programs-surveys/ahs.html

[105] Hernández, D. (2016). Understanding 'energy insecurity' and why it matters to health. *Social Science & Medicine, 167, 1-10.* Retrieved from http://www.sciencedirect.com/science/article/pii/S0277953616304658

[106] Ibid

[107] Hernández, D. (2016). Understanding 'energy insecurity' and why it matters to health. *Social Science & Medicine, 167, 1-10.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/27592003

[108] Thomson, H., Thomas, S., Sellström, E., Petticrew, M. (2009). The Health Impacts of Housing Improvement: A Systematic Review of Intervention Studies from 1887 to 2007. *American Journal of Public Health*, S681-S692 Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19890174

Tonn, B. (2014). Non-energy Benefits from the Weatherization Assistance Program. *Oak Ridge National Laboratory*. Retrieved from http://weatherization.ornl.gov/pdfs/ORNL_CON-484.pdf

William, J., William, F. (2000). Health and Productivity Gains from Better Indoor Environments and their Relationship with Building Energy Efficiency. *Annual Review of Energy and the Environment, 537-66.* Retrieved from http://constructiondurable.com/docs/1_Etude_Bill_FISK.pdf

[109] Cook. J.T. et al. (2008). A Brief Indicator of Household Energy Security: Associations with Food Security, Child Health, and Child Development in US Infants and Toddlers. *Pediatrics*, 122(4):e867-75. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18829785

[10] Cook, J.T., & Frank, DA. (2008). Food Security, Poverty, and Human Development in the United States. *Annals of the New York Academy of Sciences*,1136: 193–209. Retrieved from doi:10.1196/annals.1425.001

[111] Ibid

[112] Ibid

[113] Ibid

[114] Hernández, D. (2016). Understanding 'energy insecurity' and why it matters to health. *Social Science & Medicine, 167, 1-10.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/27592003

[115] Hacker, J. (2011). Understanding Economic Insecurity: The Downward Spiral of the Middle Class. Communities & Banking, Fall Federal Reserve Bank of Boston. Retrieved from https://www.bostonfed.org/publications/communities-and-banking.aspx

[116] Crowley, S. (2003). The affordable housing crisis: Residential mobility of poor families and school mobility of poor children. *Journal of Negro Education, 72 (1): 22-38.* Retrieved from http://www.jstor.org/stable/3211288

[117] U.S. Department of Housing and Urban Development. (2015). The 2015 Annual Homeless Assessment Report (AHAR) to Congress. Part 1: Point-in-Time Estimates of Homelessness. Retrieved from https://www.hudexchange.info/resources/documents/2015-AHAR-Part-1.pdf

[118] Shinn, M., Rog, D., Culhane, D. (2005). Family Homelessness: Background Research Findings and Policy *Options. University of Pennsylvania School of Social Policy and Practice Departmental Papers*. Retrieved from https://pdfs.semanticscholar.org/7764/698bc0817371fd7ae26c6a05d144654f86e2.pdf

[119] Suglia, S., Duarte, S., Sandel, M. (2011). Housing Quality, Housing Instability, and Maternal Mental Health. *Journal of Urban Health*, 88: 1105. Retrieved from: https://www.ncbi.nlm.nih.gov/pubmed/21647798

[120] U.S. Department of Health and Human Services. (2008). The Effects of Childhood Stress on Health across the Lifespan. *Centers for Disease Control and Prevention*. Retrieved from http://health-equity.lib.umd.edu/932/1/Childhood_Stress.pdf

[121] Mueller, E., & Tighe, J.R. (2007). Making the Case for Affordable Housing: Connecting Housing with Health and Education Outcomes. *Journal of Planning Literature, Vol. 21, No. 4*. Retrieved from http://journals.sagepub.com/doi/abs/10.1177/0885412207299653

[122] Annie E. Casey Foundation. (2010). Early Warning! Why Reading by the End of Third Grade Matters. Retrieved from http://www.aecf.org/resources/early-warning-why-reading-by-the-end-of-third-grade-matters/

[123] Ibid

[124] Dean, B., et al. (2010). Uncontrolled Asthma: Assessing Quality of Life and Productivity of Children and Their Caregivers using a Cross-Sectional Internet-Based Survey. *Health Quality Life Outcomes. 8; 8:96*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20825674

[125] Acs, G. & Nichols, A. (2007). Low-Income Workers and Their Employers: Characteristics and Challenges. *The Urban Institute*. Retrieved from: https://www.urban.org/sites/default/files/publication/46656/411532-Low-Income-Workers-and-Their-Employers.PDF

[126] Sharkey, P. (2012). Residential Mobility and the Reproduction of Unequal Neighborhoods. *Cityscape: A Journal of Policy Development and Research, Vol. 14 No. 3 (2012)*. Retrieved from https://www.jstor.org/stable/41958938

[127] Feldman, R. (2002). The Affordable Housing Shortage: Considering the Problem, Causes and Solutions. *Federal Reserve Bank of Minneapolis, Bank and Policy Paper 02-2*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.194.4810&rep=rep1&type=pdf

[128] Eggers, F., & Moumen, F. (2013). American Housing Survey a Measure of (Poor) Housing Quality. *US Department of Housing and Urban Development Office of Policy Development and Research*. Retrieved from https://www.huduser.gov/portal/publications/ahsrep/AHS_hsg_quality.html

Feldman. R. (2002). The Affordable Housing Shortage: Considering the Problem, Causes and Solutions. Federal Reserve Bank of Minneapolis, Bank and Policy Paper 02-2. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.194.4810&rep=rep1&type=pdf

[129] US Department of Housing and Urban Development. (2013). Advancing Healthy Housing: A Strategy for Action. Retrieved from http://portal.hud.gov/hudportal/documents/huddoc?id=AHHASA_2-19.pdf

[130] US Department of Housing and Urban Development. (2015). Worst Case Housing Needs: 2015 Report to Congress. *HUD PD&R*. Retrieved from https://www.huduser.gov/portal/publications/affhsg/wc_HsgNeeds15.html

[131] Braubach, M., & Fairburn, J. (2010). Social Inequities in Environmental Risks Associated with Housing and Residential Location: A Review of Evidence. *European Journal of Public Health, 20(1): 36-42*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20047933

Joint Center for Housing Studies. (2012). The State of the Nation's Housing: 2012. Retrieved from http://www.jchs.harvard.edu/research/publications/state-nation%E2%80%99s-housing-2012

Jacobs, D. (2011). Environmental Health Disparities in Housing. *American Journal of Public Health, Vol 101 S115-122*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3222490/

DiGuiseppi, C., Jacobs, D., Phlem, K., Mickalide, A., Ormandy, D. (2010). Housing Interventions and Control of Injury-Related Structural Deficiencies: A Review of the Evidence. *Journal of Public Health Management Practice, 16(5): S34-S43*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20689373

[132] Healthy People 2020. (2010) Healthy People 2020: An Opportunity to Address the Societal Determinants of Health in the United States. Secretary's Advisory Committee on Health Promotion and Disease Prevention Objectives for 2020. Retrieved from http://www.healthypeople.gov/2010/hp2020/advisory/SocietalDeterminantsHealth.htm

World Health Organization. (2005). Report on the Technical Meeting on Quantifying Disease from Inadequate Housing. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0007/98674/EBD_Bonn_Report.pdf;

Sharkey, P. (2012) Residential Mobility and the Reproduction of Unequal Neighborhoods. *Cityscape: A Journal of Policy Development and Research ,Vol. 14 No. 3 (2012)*. Retrieved from https://www.jstor.org/stable/41958938

[133] Thomson, H., Thomas, S., Sellstrom, E., Petticrew, M. (2013) Housing Improvements for Health and associated socio-economic outcomes. Cochrane Database Syst Rev. 28;(2). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23450585

[134] US Environmental Protection Agency. (2017). Sources of Combustion Products: An Introduction to Indoor Air Quality. Retrieved from https://www.epa.gov/indoor-air-quality-iaq/sources-combustion-products-introduction-indoor-air-quality

[135] CDC Healthy Housing Reference Manual (2009). Indoor Pollutants and Toxic Materials (Ch.5). Retrieved from https://www.cdc.gov/nceh/publications/books/housing/cha05.htm

[136] US Environmental Protection Agency. (2017). Sources of Combustion Products. An Introduction to Indoor Air Quality. Retrieved from https://www.epa.gov/indoor-air-quality-iaq/sources-combustion-products-introduction-indoor-air-quality

[137] US Environmental Protection Agency. (2014). Indoor Air Quality in Homes. Retrieved from http://www.epa.gov/iaq/homes/index.html

[138] US Environmental Protection Agency. (2014). Indoor Air Quality in Homes. Retrieved from http://www.epa.gov/iaq/homes/index.html

[139] Franchi, M., Carrer, F., Kotzias, D., Rameckers. E.M., Seppänen, O., van Bronswijk, J.E., Viegi, G., Gilder, J.A., Valovirta. E. (2006). Working towards healthy air in dwellings in Europe. *Allergy, 61: 864–868*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16792586

[140] Occupational Safety and Health Administration. (2011). Indoor Air Quality in Commercial and Institutional Buildings. *OSHA, 3430-04*. Retrieved from https://www.osha.gov/Publications/3430indoor-air-quality-sm.pdf

[141] Ibid

[142] US Environmental Protection Agency. (2017). Introduction to Indoor Air Quality. Retrieved from https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality

[143] *Ibid*

[144] Liuhua, S., Zanobetti, A., Kloog, I., Coull, B., Koutrakis, P., Melly, S., Schqartz, J. (2016). Low-Concentration PM2.5 and Mortality: Estimating Acute and Chronic Effects in a Population-Based Study. *Environmental Health Perspectives 124(1):46-52*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26038801

[145] Brook, R., Rajagopalan, S., Pope, C., Brook, J., Bhatnagar, A. Diez-Roux, A., … Holguin, F. (2010). Particulate matter air pollution and cardiovascular disease an update to the scientific statement from the American Heart Association. *Circulation, 121, no. 21: 2331-2378*. Retrieved from http://circ.ahajournals.org/content/121/21/2331

[146] Ibid

[147] Ibid

[148] Wilbur, S., Williams. M, Williams. R, et al. (2012). Toxicological Profile for Carbon Monoxide. *Agency for Toxic Substances and Disease Registry*. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK153692/

[149] Ibid.

[150] Walker, S. (2011). Carbon Monoxide - Leading Cause of Poisoning Deaths. *California Real Estate Inspection Association*. Retrieved from http://www.creia.org/carbon-monoxide---leading-cause-of-poisoning-deaths

[151] *Ibid*.

[152] Centers for Disease Control and Prevention. (2011). Carbon Monoxide Exposures --United States, 2000-2009. *Morbidity and Mortality Weekly Report (MMWR) Vol. 60 No.30 (2011); 1014-1017*. Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6030a2.htm

[153] DiGuiseppi, C., Jacobs, E., Phelan, K., Mickalide, A., Ormandy. D. (2010). Housing Interventions and Control of Injury-Related Structural Deficiencies: A Review of the Evidence. *Journal of public health management and practice: 16, no. 5 Suppl: S34*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20689373

[154] *Ibid*.

[155] Raub, J., Mathieu-Nolf, M., Hampson, N., Thom, S. (2000). Carbon monoxide poisoning—a public health perspective. *Toxicology 145, no. 1 (2000): 1-14*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10771127

[156] King, M., & Bailey, C. (2007). Carbon Monoxide-Related Deaths- United States, 1999-2004. *National Center for Environmental Health, CDC, Morbidity and Mortality Weekly Report (MMWR) Vol. 56 No.50; 1309-1312*. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5650a1.htm

[157] US Environmental Protection Agency (2012). Toxic Substances Portal, Carbon Monoxide. *Agency for Toxic Substances & Disease Registry*. Retrieved from http://www.atsdr.cdc.gov/toxprofiles/tp201-c2.pdf

[158] DiGuiseppi. C. Jacobs, E., Phelan, K., Mickalide, A., Ormandy. D. (2010). Housing Interventions and Control of Injury-Related Structural Deficiencies: A Review of the Evidence. *Journal of public health management and practice: 16, no. 5 Suppl: S34*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20689373

[159] Raub. J., Mathieu-Nolf, M., Hampson, N., Thom, S. (2000). Carbon monoxide poisoning—a public health perspective. *Toxicology 145, no. 1 (2000): 1-14*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10771127

[160] Centers for Disease Control and Prevention (2015). Carbon Monoxide Poisoning: Frequently Asked Questions. Retrieved from http://www.cdc.gov/co/faqs.htm

[161] Agency for Toxic Substances & Disease Registry (2012). Toxic Substances Portal: Carbon Monoxide. Centers for Disease Control and Prevention. Retrieved from https://www.atsdr.cdc.gov/toxprofiles/TP.asp?id=1145&tid=253

[162] *Ibid.*

[163] *Ibid.*

[164] *Ibid.*

[165] US Environmental Protection Agency. (2009) Integrated science assessment for particulate matter. Washington, DC: U.S. Retrieved from: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=216546

[166] Brook, R., Rajagopalan, S., Pope, C., Brook, J., Bhatnagar, A. Diez-Roux, A., …Holguin, F. (2010). Particulate matter air pollution and cardiovascular disease an update to the scientific statement from the American Heart Association. *Circulation,121, no. 21 (2010): 2331-2378*. Retrieved from http://circ.ahajournals.org/content/121/21/2331

[167] US Environmental Protection Agency (2014). Particulate Matter, Health. Retrieved from http://www.epa.gov/airquality/particlepollution/health.html

[168] Zanobetti, A., Franklin, M., Koutrakis, P., Schwartz. J. (2009). Fine particulate air pollution and its components in association with cause-specific emergency admissions. *Environ Health 8, no. 58: 58*. Retrieved from https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-8-58

[169] Brook, R., Rajagopalan, S., Pope, C., Brook, J., Bhatnagar, A. Diez-Roux, A., …Holguin, F. (2010). Particulate matter air pollution and cardiovascular disease an update to the scientific statement from the American Heart Association. *Circulation,121, no. 21 (2010): 2331-2378*. Retrieved from http://circ.ahajournals.org/content/121/21/2331

[170] Ibid.

[171] *Ibid.*

[172] Krewski, D., Jerrett, M., Burnett, R.T., Ma, R., Hughes, E., Shi, Y., Turner. M. (2009). Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. *Health Effects Institute, 140: 5-114*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19627030

[173] Schwartz, J., Coull, B., Laden, F., Ryan, L. (2008). The effect of dose and timing of dose on the association between airborne particles and survival. *Environmental Health Perspectives, 64-69*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18197301

[174] National Academies of Sciences, Engineering, and Medicine. (2016). Health Risks of Indoor Exposure to Particulate Matter. *The National Academies Press*. Retrieved from doi: 10.17226/23531.

[175] National Academies of Sciences, Engineering, and Medicine. (2016). Health Risks of Indoor Exposure to Particulate Matter. *The National Academies Press*. Retrieved from doi: 10.17226/23531; Chen, C. & Zhao, B. (2011). Review of relationship between indoor and outdoor particles: I/O ratio, infiltration factor and penetration factor. Atmospheric Environment 45(2):275–288. Retrieved from http://www.sciencedirect.com/science/article/pii/S1352231010008241

[176] Clark, N., Allen, R., Hystad, P., Wallace, L., Dell, S., Foty, R., Dabek-Zlotorzynska, E., Evans, G., Wheeler, A. (2010) Exploring variation and predictors of residential fine particulate matter infiltration. *International journal of environmental research and public health 7, no. 8: 3211-3224*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20948956

[177] Isaxon, C., Gudmundsson, A. Nordin, E., Lönnblad, L., Dahl, A., Wieslander, G., Bohgard, M., Wierzbicka, A. (2015). Contribution of indoor-generated particles to residential exposure. *Atmospheric Environment 106:458–466*. Retrieved from http://www.sciencedirect.com/science/article/pii/S1352231014005834

[178] National Academies of Sciences, Engineering, and Medicine. (2016). Health risks of indoor exposure to particulate matter. *The National Academies Press*. Retrieved from doi: 10.17226/23531.

[179] Hesterberg, W., Bunn, W., McClellan, R., Hamade, A., Long, C., Valberg, P. (2009). Critical review of the human data on short-term nitrogen dioxide (NO2) exposures: Evidence for NO2 no-effect levels. *Critical reviews in toxicology 39, no. 9, 743-781*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19852560

[180] Cyrys, J., Heinrich, J., Richter, K., Wölke, G., Wichmann, H. (2000). Sources and concentrations of indoor nitrogen dioxide in Hamburg (west Germany) and Erfurt (east Germany). *Science of the Total Environment 250, no. 1,51-62*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0048969700003612

[181] WHO Working Group (2003). Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide. *World Health Organization*. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0005/112199/E79097.pdf

[182] *Ibid.*

[183] Latzin, P., Röösli, M., Huss, A., Kuehni, C.E., & Frey, U. (2009) Air pollution during pregnancy and lung function in newborns: a birth cohort study. *European Respiratory Journal* 33, no. 3: 594-603. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19010988

[184] Kattan, M., Gergen, P., Eggleston, P., Visness, C.M., & Mitchell, H.E. (2007). Health effects of indoor nitrogen dioxide and passive smoking on urban asthmatic children. *Journal of Allergy and Clinical Immunology* 120(3): 618-624. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17582483

[185] *Ibid.*

[186] Gillespie-Bennett, J., Pierse, N., Wickens, K., Crane, J., & Howden-Chapman, P. (2011). The respiratory health effects of nitrogen dioxide in children with asthma. *European Respiratory Journal* 38(2): 303-309. Retrieved from http://erj.ersjournals.com/content/38/2/303

[187] Hesterberg, T.W., Bunn, W.B., McClellan, R.O., Hamade, A.K., Long, C.M., Valberg, P.A. (2009). Critical review of the human data on short-term nitrogen dioxide (NO2) exposures: evidence for NO2 no-effect levels. *Critical Reviews in Toxicology 39(9): 743-81*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19852560

[188] *Ibid.*

[189] *Ibid.*

[190] US Department of Energy (2011). *Weatherization Program Notice 11-6*. Retrieved from https://energy.gov/eere/wipo/downloads/wpn-11-6-health-and-safety-guidance

[191] Gillespie-Bennett, J., Pierse, N., Wickens, K., Crane, J., Nicholls, S., Shields, D., Boulic, M., et al. (2008) Sources of nitrogen dioxide (NO2) in New Zealand homes: findings from a community randomized controlled trial of heater substitutions. *Indoor Air* 18(6): 521-528. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19120502

[192] Tonn, B., et al. (2014). Health and household-related benefits attributable to the Weatherization Assistance Program. *Oak Ridge National Laboratory*. Retrieved from http://weatherization.ornl.gov/Retrospectivepdfs/ORNL_TM-2014_345.pdf

[193] *Ibid*, 64

[194] US Department of Energy (2011). *Weatherization Program Notice 11-6*. Retrieved from https://energy.gov/eere/wipo/downloads/wpn-11-6-health-and-safety-guidance

[195] Francisco, P.W., Jacobs, D. E., Targos, L., Dixon, S. L., Breysse, J., Rose, W., & Cali, S. (2016). Ventilation, indoor air quality, and health in homes undergoing weatherization. *Indoor Air*. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/ina.12325/abstract

[196] *Ibid.*

[197] *Ibid.*

[198] Bell, M.L., Ebisu, K., Peng, R.D., & Dominici, F. (2009). Adverse health effects of particulate air pollution: modification by air conditioning. *Epidemiology* 20(5): 682. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19535984

[199] Fabian, P., Adamkiewicz, G., & Levy, J.I. (2012). Simulating indoor concentrations of NO2 and PM2.5 in multifamily housing for use in health-based intervention modeling. *Indoor Air* 22(1): 12-23. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3248980/

[200] *Ibid.*

[201] Hänninen, O.O., Palonen, J., Tuomisto, J.T., Yli-Tuomi, T., Seppänen, O., & Jantunen, M.J. (2005). Reduction potential of urban PM2.5 mortality risk using modern ventilation systems in buildings. *Indoor Air 15(4): 246-256.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15982271

[202] Tonn, B., et al. (2014). Health and household-related benefits attributable to the Weatherization Assistance Program. *Oak Ridge National Laboratory*. Retrieved from http://weatherization.ornl.gov/Retrospectivepdfs/ORNL_TM-2014_345.pdf

[203] MacIntosh, D.L., Minegishi, T., Kaufman, M., Baker, B.J., Allen, J.G., Levy, J.I., & Myatt, T.A. (2010). The benefits of whole-house in-duct air cleaning in reducing exposures to fine particulate matter of outdoor origin: a modeling analysis. *Journal of Exposure Science and Environmental Epidemiology 20(2): 213-224*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19319161

[204] *Ibid.*

[205] *Ibid.*

[206] US Environmental Protection Agency. (2013). An introduction to indoor air quality: volatile organic compounds (VOCs). Retrieved from http://www.epa.gov/iaq/voc.html

[207] Kim, K.H., Jahan, S.A., and Lee, J.T. (2011) Exposure to formaldehyde and its potential human health hazards. *Journal of Environmental Science and Health, Part C 29(4)*: 277-299. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22107164

[208] Bernstein, J.A., Alexis, N., Bacchus, H., Bernstein, L.I., Fritz, P., Horner, E., Ni, L., Mason, S., Nel, A., Oullette, J., Reijula, K., Reponen, T., Seltzer, J., Smith, A., Tarlo, S.M. (2008). The health effects of non-industrial indoor air pollution. *The Journal of Allergy and Clinical Immunology, 121(3)*: 585-91. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18155285

[209] McGwin, Jr., G., Lienert, J., & Kennedy Jr., J.I. (2010). Formaldehyde exposure and asthma in children: a systematic review. *Environmental health perspectives 118(3): 313*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2854756/

[210] *Ibid.*

[211] Guo, P., Yokoyama, K., Piao, F., Sakai, K., Khalequzzaman, M., Kamijima, M., Nakajima, T., & Kitamura, F. (2013). Sick building syndrome by indoor air pollution in Dalian, China. *International Journal of Environmental Research and Public Health 10(4)*: 1489-1504. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23579877

[212] Jung, J.H., Choi, B.W., Kim, M.H., Baek, S.O., Lee, G.W. & Shon, B.H. (2012). The characteristics of the appearance and health risks of volatile organic compounds in industrial (Pohang, Ulsan) and non-industrial (Gyeongju) areas." *Environmental Health and Toxicology* 27. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22639739

[213] Kim, K.H. (2011). Exposure to formaldehyde and its potential human health hazards.

[214] *Ibid.*

[215] Salthammer, T., Mentese, S. & Marutzky, R. (2010). Formaldehyde in the indoor environment. *Chemical Reviews 110(4)*: 2536-2572. Retrieved from http://pubs.acs.org/doi/abs/10.1021/cr800399g

[216] Golden, R. (2011). Identifying an indoor air exposure limit for formaldehyde considering both irritation and cancer hazards. *Critical Reviews in Toxicology 41(8)*: 672-721. Retrieved from http://pubs.acs.org/doi/abs/10.1021/cr800399g

[217] *Ibid.*

[218] McGwin, Jr., G., (2010). Formaldehyde exposure and asthma in children.

[219] Kim, K.H. (2011). Exposure to formaldehyde and its potential human health hazards.

[220] *Ibid.*

[221] Checkoway, H., Boffetta, P., Mundt, D.J., & Mundt, K.A. (2012). Critical review and synthesis of the epidemiologic evidence on formaldehyde exposure and risk of leukemia and other lymphohematopoietic malignancies. *Cancer Causes & Control 23(11)*: 1747-1766. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3465649/

[222] US Department of Energy (2011). Weatherization Program Notice 11-6.

[223] *Ibid*, 6

[224] US Environmental Protection Agency (2016). An Introduction to Indoor Air Quality: Volatile Organic Compounds. Retrieved from https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality

[225] US Environmental Protection Agency (2013). An Introduction to Indoor Air Quality: Formaldehyde. Retrieved from https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality

[226] Francisco, P.W. (2016). Ventilation, indoor air quality, and health in homes undergoing weatherization.

[227] Ibid.

[228] Tonn, B., et al. (2014). Health and household-related benefits attributable to the Weatherization Assistance Program.

[229] Vogiannis, E.G., & Nikolopoulos, D. (2014). Radon sources and associated risk in terms of exposure and dose. *Frontiers in Public Health* 2: 207. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4283434/

[230] Bräuner, E.V., Andersen, Z.J., Andersen, C.E., Pedersen, C., Gravesen, P., Ulbak, K., Hertel, O., Loft, S., & Raaschou-Nielsen, O. (2013). "Residential radon and brain tumour incidence in a Danish cohort." *PL o S One* 8(9). Retrieved from http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0074435

[231] Chahine, T., Schultz, B.D., Zartarian, V.G., Xue, J., Subramanian, S.V., & Levy, J.I. (2011). Modeling joint exposures and health outcomes for cumulative risk assessment: the case of radon and smoking. *International Journal of Environmental Research and Public Health* 8(9): 3688-3711. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3194111/

[232] *Ibid.*

[233] Pérez-Ríos, M., Barros-Dios, J.M., Montes-Martínez, A., & Ruano-Ravina, A. (2010). Attributable mortality to radon exposure in Galicia, Spain. Is it necessary to act in the face of this health problem? *BMC Public Health 10(1)*: 256. Retrieved from https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-10-256

[234] Axelsson, G., Andersson, E.M. & Barregard, L. (2015). Lung cancer risk from radon exposure in dwellings in Sweden: how many cases can be prevented if radon levels are lowered? *Cancer Causes & Control* 26(4): 541-547. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25677843

[235] Turner, M.C., Krewski, D., Chen, Y., Pope, C.A., Gapstur, S. & Thun, M.J. (2011). Radon and lung cancer in the American Cancer Society cohort. *Cancer Epidemiology Biomarkers & Prevention* 20(3): 438-448. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21212062

[236] *Ibid.*

[237] *Ibid.*

[238] Bräuner, E.V., et al. (2013). Residential radon and brain tumour incidence in a Danish cohort.

[239] *Ibid*

[240] *Ibid.*

[241] Turner, M.C., Krewski, D., Chen, Y., Pope, C.A., Gapstur, S. & Thun, M.J. (2012). Radon and COPD mortality in the American Cancer Society cohort. *European Respiratory Journal* 39(5): 1113-9. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22005921

[242] *Ibid.*

[243] US Department of Energy (2011). Weatherization Program Notice 11-6.

[244] Manuel, J. (2011). Avoiding health pitfalls of home energy-efficiency retrofits. *Environmental Health Perspectives 119(2)*: A76. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3040626/

[245] Francisco, P.W. (2016). Ventilation, indoor air quality, and health in homes undergoing weatherization.

[246] Pigg, S. (2014) National Weatherization Assistance Program impact evaluation: impact of exhaust-only ventilation on radon and indoor humidity –a field investigation. *Oak Ridge National Laboratory*. Retrieved from http://weatherization.ornl.gov/Retrospectivepdfs/ORNL_TM-2014_367.pdf

[247] Gray, A. & Darby, S. (2009). Lung cancer deaths from indoor radon and the cost effectiveness and potential of policies to reduce them. *British Medical Journal, 338*. Retrieved from http://www.bmj.com/content/338/bmj.a3110

[248] Lantz, P.M., Mendez, D., & Philbert, M.A.. (2013) Radon, smoking, and lung cancer: the need to refocus radon control policy. *American Journal of Public Health 103(3)*: 443-447. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3673501/

[249] Peterson, E., Aker, A., Kim, J., Li, Y., Brand, K., & Copes, R. (2013). Lung cancer risk from radon in Ontario, Canada: how many lung cancers can we prevent? *Cancer Causes & Control 24(11)* Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3824583/

[250] US Environmental Protection Agency. (2016) A Citizen's Guide to Radon: The guide to protecting yourself and your family from Radon. *EPA 402/K-12/002* Retrieved from https://www.epa.gov/sites/production/files/2016-12/documents/2016_a_citizens_guide_to_radon.pdf

[251] Gray, A. & Darby, S. (2009). Lung cancer deaths from indoor radon and the cost effectiveness and potential of policies to reduce them. *British Medical Journal, 338*. Retrieved from http://www.bmj.com/content/338/bmj.a3110

[252] *Ibid*.

[253] Axelsson, G., Andersson, E., and Barregard, L. (2015). Lung cancer risk from radon exposure in dwellings in Sweden: how many cases can be prevented if radon levels are lowered?. *Cancer Causes and Control*. Retrieved from https://link.springer.com/content/pdf/10.1007%2Fs10552-015-0531-6.pdf.

[254] World Health Organization. (2016) Radon and health. *Media Center*. Accessed on 2/5/2017 http://www.who.int/mediacentre/factsheets/fs291/en/

[255] Comhair, S., Gaston, B., Ricci, K., Hammel, J., Dweik, R., Teague, W., … and Erzurum, S. (2011). Detrimental Effects of Environmental Tobacco Smoke in Relation to Asthma Severity. PLoS ONE6(5): e18574. https://doi.org/10.1371/journal.pone.0018574

[256] U.S. Department of Health and Human Services. (2006). *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General*. Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK44324/

[257] U.S. Department of Health and Human Services. (2014). *The Health Consequences of Smoking—50 Years of Progress. A Report of the Surgeon General*. Atlanta: GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. Printed with corrections, January 2014.

[258] Ibid.

[259] U.S. Department of Housing and Urban Development. (2016). 24 CFR Parts 965 and 966: Instituting Smoke-Free Public Housing. https://portal.hud.gov/hudportal/documents/huddoc?id=smokefreephfinalrule.pdf

[260] U.S. Department of Health and Human Services. (2006) "The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General."

[261] Wilson, K.M., Klein, J.D., Blumkin, A.K., Gottlieb, M. and Winickoff, J.P. (2011) Tobacco-Smoke Exposure in Children Who Live in Multiunit Housing. Pediatrics, 127, 85-92. http://dx.doi.org/10.1542/peds.2010-2046

[262] U.S. Department of Health and Human Services. (2004). The Health Consequences of Smoking: A Report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.

[263] U.S. Department of Health and Human Services. (2006). *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General*. Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK44324/

[264] U.S. Department of Health and Human Services. (2004). *The Health Consequences of Smoking: A Report of the Surgeon General*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.

[265] Ibid. at 556

[266] Ibid. at 559

[267] Ibid., at 319

[268] U.S. Department of Health and Human Services. (2006). *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General.* Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK44324/

[269] Kanchongkittiphon, W., Mendell, M., Gaffin, J., Wang, G., and Phipatanakui, W. (2015). Indoor Environmental Exposures and Exacerbation of Asthma: An Update to the 2000 Review by the Institute of Medicine. *Environmental Health Perspectives*, 123 (1), 6–20. PMC. Web. 1 Apr. 2017. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/25303775

[270] U.S. Department of Health and Human Services. (2006). *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General.* Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK44324/

[271] Anderson, H.R., and Cook, D. (1997). Passive smoking and sudden infant death syndrome: review of the epidemiological evidence. *Thorax*, 52(11), 1003-1009. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/9487351

[272] U.S. Department of Health and Human Services. (2006). *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General.* Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK44324/

[273] U.S. Department of Health and Human Services. (2001). *Women and Smoking. A Report of the Surgeon General.* Atlanta (GA): Centers for Disease Control and Prevention (US). Mar. Available from: https://www.ncbi.nlm.nih.gov/books/NBK44303/

[274] Windham, G., Eaton, A., Hopkins, B. (1999). Evidence for an association between environmental tobacco smoke exposure and birthweight: a meta-analysis and new data. *Pediatric Perinatal Epidemiology*, 13, 35–57. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/9987784

[275] Windham, G., Hopkins, B., Fenster, L, and Swan, S. (2000). Prenatal Active or Passive Tobacco Smoke Exposure and the Risk of Preterm Delivery or Low Birth Weight. *Epidemiology*, 11 (no. 4), 427-33. http://www.jstor.org/stable/3703969

[276] US Dept. HHS, *The Health Consequences of Involuntary Exposure to Tobacco Smoke*

[277] US Department of Health and Human Services National Center for Health Statistics (2015). Health, United States, 2015: *With Special Feature on Racial and Ethnic Health Disparities* Retrieved from https://www.cdc.gov/nchs/data/hus/hus15.pdf#019

[278] Rosenlund M, Berglind N, Gustavsson A, Reuterwall C, Hallqvist J, Nyberg F, Pershagen G. (2001). Environmental tobacco smoke and myocardial infarction among never-smokers in the Stockholm Heart Epidemiology Program (SHEEP). *Epidemiology 12(5)*: 558–64. Retrieved from http://www.jstor.org/stable/3703882

[279] US Department of Health and Human Services. (2006). *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General.*

[280] Ibid.

[281] Ibid

[282] Ridge, C., McErlean, A., and Ginsberg, M. (2013). Epidemiology of lung cancer. *Seminars in interventional radiology*, 30(02), pp. 093-098. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3709917/

[283] U.S. Department of Health and Human Services. (2006). The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General.

[284] Ridge, C., McErlean, A., and Ginsberg, M. (2013). Epidemiology of lung cancer. *Seminars in interventional radiology*, 30(02), pp. 093-098. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3709917/

[285] Wang, L., Lubin, J., Zhang, S., Metayer, C., Xia, Y., Brenner, A., Shang, B., Wang, Z., and Kleinerman, R. (2000) Lung cancer and environmental tobacco smoke in a non-industrial area of China. *International journal of cancer, 88* (1), 139-145. Rerieved from https://www.ncbi.nlm.nih.gov/pubmed/10962452

[286] Ridge, C., (2006) Epidemiology of lung cancer.

[287] Lantz, P. M., Mendez, D., & Philbert, M. A. (2013). Radon, smoking, and lung cancer: The need to refocus radon control policy. American Journal of Public Health, 103(3), 443-447. Retrieved from DOI: 10.2105/AJPH.2012.300926

[288] Morabia, A., Bernstein, M., Bouchardy, I., Kurtz, J., Morris, M. (2000). Breast cancer and active and passive smoking: the role of the N-acetyltransferase 2 genotype. *American Journal of Epidemiology*, 152(3), 226-232. Retrieved from https://doi.org/10.1093/aje/152.3.226

[289] Ibid.

[290] US Department of Health and Human Services. (2006). *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General.*

[291] Ibid.

[292] Levy, D. T., Romano, E., and Mumford, E. (2004). Recent trends in home and work smoking bans. *Tobacco control*, 13 (3), 258-263. Retrieved from http://dx.doi.org/10.1136/tc.2003.006056

[293] Tynan, M., Holmes, C., Promoff, G., Hallett, C., Hopkins, M., and Frick, B. (2016). State and Local Comprehensive Smoke-Free Laws for Worksites, Restaurants, and Bars — United States, 2015. *MMWR Morb Mortal Wkly Rep*, 65, 623–626. DOI: http://dx.doi.org/10.15585/mmwr.mm6524a4

[294] Fabian, M., Lee, S., Underhill, L., Vermeer, K., Adamkiewicz, G., Levy, J. (2016). Modeling Environmental Tobacco Smoke (ETS) Infiltration in Low-Income Multifamily Housing before and after Building Energy Retrofits. *Ed. Paul B. Tchounwou. International Journal of Environmental Research and Public Health, 13 (3).* Retrieved from doi:10.3390/ijerph13030327

[295] US Department of Health and Human Services. (2006). *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General.*

[296] Bohac, D. L., Hewett, M. J., Hammond, S. K. and Grimsrud, D. T. (2011). Secondhand smoke transfer and reductions by air sealing and ventilation in multiunit buildings: PFT and nicotine verification. *Indoor Air*, 21, 36–44. DOI: 10.1111/j.1600-0668.2010.00680.x

[297] Fabian (2016). Modeling Environmental Tobacco Smoke (ETS) Infiltration in Low-Income Multifamily Housing before and after Building Energy Retrofits.

[298] Ibid.

[299] Fabian (2016). Modeling Environmental Tobacco Smoke (ETS) Infiltration in Low-Income Multifamily Housing before and after Building Energy Retrofits.; Bohac (2011). Secondhand smoke transfer and reductions by air sealing and ventilation in multiunit buildings: PFT and nicotine verification.

[300] Ibid.

[301] Mason, J., Wheeler, W., and Brown M. (2015). The economic burden of exposure to secondhand smoke for child and adult never smokers residing in U.S. public housing. *Public Health Reports, 130 (3), 230-234. DOI: 10.1177/003335491513000310*

[302] King, B.A., Peck, R.M., and Babb, S.D. (2013). Cost savings associated with prohibiting smoking in U.S. subsidized housing. *American Journal of Preventative Medicine*, 44 (6), 631-634. DOI: 10.1016/j.amepre.2013.01.024

[303] U.S. Environmental Protection Agency. (May 2012). *The President's Task Force on Environmental Health Risks and Safety Risks to Children: Coordinated Federal Action Plan to Reduce Racial and Ethnic Disparities*. Accessed on 3/9/17: https://www.epa.gov/asthma/coordinated-federal-action-plan-reduce-racial-and-ethnic-asthma-disparities

[304] U.S. Consumer Product Safety Commission. *Biological Pollutants in the Home*. Accessed on 7/13/2013: http://www.cpsc.gov/en/Safety-Education/Safety-Guides/Home/Biological-Pollutants-in-Your-Home/

[305] Krieger, J., Jacobs, D., Ashley, P., Baeder, A., Chew, G., Dearborn, D., Hynes, H.P., Miller, J.D., Morley, R., Rabito, F., Zeldin, D. (2010) Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence. *Journal of public health management and practice 16(5)*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20689369

[306] *Ibid.*

[307] Robert Wood Johnson Commission to Build a Healthier America. (2009). *Beyond health care: new directions to a healthier America*. Retrieved from http://www.commissiononhealth.org/PDF/11f12754-e8ff-408b-9451-6456d939b15f/Executive-Summary_FINAL.pdf

[308] Fisk, W. Indoor Dampness, Biological Contaminants and Health. *Indoor Air Quality Scientific Findings Resource Bank*. Accessed 7/13/2013: https://iaqscience.lbl.gov/dampness-summary

[309] Ahluwalia, S.K., and Matsui, E.C. (2011) The indoor environment and its effects on childhood asthma. *Current opinion in allergy and clinical immunology*, 11 (2), 137-143. doi: 10.1097/ACI.0b013e3283445921

[310] Weinmayr, G., Gehring, U., Genuneit, J., Büchele, G., Kleiner, A., Siebers, R., Wickens, K., Crane, J., Brunekreef, B., Strachan D.P. (2013) Dampness and moulds in relation to respiratory and allergic symptoms in children: results from Phase Two of the International Study of Asthma and Allergies in Childhood (ISAAC Phase Two). *Clinical & Experimental Allergy*, 43 (7), 762-774. DOI: 10.1111/cea.12107

[311] Wang, Z., Shalat, S.L., Black, K., Lioy, P.J., Stambler, A.A., Emoekpere O.H., Hernandez, M., Han, T., Ramagopal, M., Mainelis, G. (2012). Use of a robotic sampling platform to assess young children's exposure to indoor bioaerosols. *Indoor air*, 22 (2), 159-169. DOI: 10.1111/j.1600-0668.2011.00749.x

[312] Blanc, P., Quinlan, P., Katz, P., Balmes, J,. Trupin, L., Cisternas, M., Wymer, L., Vesper, S. (2013) "Higher environmental relative moldiness index values measured in homes of adults with asthma, rhinitis, or both conditions." *Environmental research*, 122, 98-101. https://doi.org/10.1016/j.envres.2013.01.002

[313] Plopper, C., Smiley-Jewell, S., Miller, L., Fanucchi, M., Evans, M., Buckpitt, A., Avdalovic, M., … Hyde, D. (2007). Asthma/allergic airways disease: does postnatal exposure to environmental toxicants promote airway pathobiology?. *Toxicologic pathology*, 35 (1), 97-110. https://doi.org/10.1080/01926230601132030

[314] Rosenfeld, L., Rudd, R., Chew, G. L., Emmons, K., and Acevedo-García, G. L. (2010). Are neighborhood-level characteristics associated with indoor allergens in the household?. *The Journal of asthma: official journal of the Association for the Care of Asthma*, 47 (1), 66. doi:10.3109/02770900903362676

[315] Reponen, T., Levin, L., Zheng, S., Vesper, S., Ryan, P., Grinshpun, S., and LeMasters, G. (2013). Family and home characteristics correlate with mold in homes. *Environmental research*, 124, 67-70. https://doi.org/10.1016/j.envres.2013.04.003

[316] Miranda, M., Galeano, M.A.O., Hale, B., and Thomann, Wayne. (2011). Crawl spaces as reservoirs for transmission of mold to the livable part of the home environment. *Reviews on environmental health*, 26 (3), 205-213. DOI: 10.1515/REVEH.2011.028

[317] Lioy, P. (2006). Employing dynamical and chemical processes for contaminant mixtures outdoors to the indoor environment: the implications for total human exposure analysis and prevention. *Journal of Exposure Science and Environmental Epidemiology*, 16 (3), 207-224. doi:10.1038/sj.jes.7500456

[318] *Ibid.*

[319] Breysse, P., Buckley, T., Williams, D., Beck, C., Jo, S., Merriman, B., Kanchanaraksa, S., … Eggleston, P. (2005). Indoor exposures to air pollutants and allergens in the homes of asthmatic children in inner-city Baltimore. *Environmental Research*, 98 (2), 167-176. DOI: 10.1016/j.envres.2004.07.018

[320] Quirós-Alcalá, L,. Bradman, A., Nishioka, M., Harnly, M., Hubbard, A., McKone, T., Ferber, J., Eskenazi, B. (2011). Pesticides in house dust from urban and farmworker households in California: an observational measurement study. *Environmental Health*, 10 (19). Retrieved from http://hdl.handle.net/1903/18885

[321] Crocker, D., Kinyota, S., Dumitru, G., Ligon, C., Herman, E., Ferdinands, J., Hopkins, D., Lawrence, B., Sipe, T. and Task Force on Community Preventive Services. (2011). Effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity: a community guide systematic review. *American journal of preventive medicine*, 41 (2), S5-S32. Retrieved from https://doi.org/10.1016/j.amepre.2011.05.012

[322] Krieger, J., Jacobs, D. E., Ashley, P. J., Baeder, A., Chew, G. L., Dearborn, D., ... Zeldin, D. C. (2010). Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence. Journal of public health management and practice: JPHMP, 16(5 Suppl). Retrived from https://www.ncbi.nlm.nih.gov/pubmed/20689369

[323] *Ibid.*

[324] U.S. Consumer Product Safety Commission. *Biological Pollutants in the Home*. Accessed on 7/13/2013: http://www.cpsc.gov/en/Safety-Education/Safety-Guides/Home/Biological-Pollutants-in-Your-Home/

[325] Eggleston, P., Butz, A., Rand, C., Curtin-Brosnan, J., Kanchanaraksa, S., Swartz, L., Breysse P., … Krishnan, J. (2005). Home environmental intervention in inner-city asthma: a randomized controlled clinical trial. *Annals of Allergy, Asthma & Immunology*, 95 (6), 518-524. Retrieved from https://doi.org/10.1016/S1081-1206(10)61012-5

[326] Carter, M., Perzanowski, M., Raymond, A., and Platts-Mills, T. (2001) Home intervention in the treatment of asthma among inner-city children. *Journal of Allergy and Clinical Immunology*, 108 (5). 732-737. DOI: http://dx.doi.org/10.1067/mai.2001.119155

[327] Krieger, J., Takaro, T., Song, L., Weaver, M. (2005). The Seattle-King County Healthy Homes Project: a randomized, controlled trial of a community health worker intervention to decrease exposure to indoor asthma triggers. *American journal of public health*, 95 (4), 652-659. DOI: 10.2105/AJPH.2004.042994

[328] *Ibid.*

[329] Breysse, J., Wendt, J., Dixon, S., Murphy, A., Wilson, J., Meurer, J., Cohn, J., and Jacobs, D. (2011). Nurse case management and housing interventions reduce allergen exposures: the Milwaukee randomized controlled trial. *Public Health Reports* 126 (no. Suppl) 189. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21563716

[330] Barnes, S., Amado, M., Portnoy, J. (2010). Reduced clinic, emergency room, and hospital utilization after home environmental assessment and case management. In *Allergy and Asthma Proceedings,* 31 (4), 317-323. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20819322

[331] Rockwell, W. (2005). Prompt remediation of water intrusion corrects the resultant mold contamination in a home. *Allergy and asthma proceedings*, 26 (4), pp. 316-318. Retrived from https://www.ncbi.nlm.nih.gov/pubmed/16270726

[332] Lignell, U., Meklin, T., Putus, T., Rintala, H., Vepsäläinen, A., Kalliokoski, P., Nevalainen, A. (2007). Effects of moisture damage and renovation on microbial conditions and pupils' health in two schools—a longitudinal analysis of five years. *Journal of Environmental Monitoring*, 9 (3), 225-233. Retrieved from http://centerforhealthyhousing.org/Portals/0/Contents/Article0626.pdf

[333] Chew, G., Wilson, J., Rabito, F., Grimsley, F., Iqbal, S., Reponen, T., Muilenberg, M., Thorne, P., Dearborn, D., and Morley, R. (2006). Mold and endotoxin levels in the aftermath of Hurricane Katrina: a pilot project of homes in New Orleans undergoing renovation. *Environmental Health Perspectives*, 1883-1889. doi: 10.1289/ehp.9258

[334] Warner, J., Frederick, J., Bryant, T., Weich, C., Raw, G., Hunter, C., Stephend, F., McIntyre, D., Warner, John. (2000). Mechanical ventilation and high-efficiency vacuum cleaning: A combined strategy of mite and mite allergen reduction in the control of mite-sensitive asthma. *Journal of allergy and clinical immunology*, 105 (1), 75-82. Retrieved from https://doi.org/10.1016/S0091-6749(00)90181-7

[335] Arlian, L., Neal, J., Morgan, M., Vyszenski-Moher, D., Rapp, C., and Alexander, A. (2001). Reducing relative humidity is a practical way to control dust mites and their allergens in homes in temperate climates. *Journal of allergy and clinical immunology,* 107 (1), 99-104. Retrieved from https://doi.org/10.1067/mai.2001.112119

[336] Sandel, M., Baeder, A., Bradman, A., Hughes, J., Mitchell, C., Shaughnessy, R., Takaro, T., Jacobs, D. (2010). Housing interventions and control of health-related chemical agents: a review of the evidence. *Journal of Public Health Management and Practice*, 16 (5), S24-S33. DOI: 10.1097/PHH.0b013e3181e3cc2a

[337] Howden-Chapman, P., Matheson, A., Crane, J., Viggers, H., Cunningham, M., Blakely, T., Cunningham, C. … Chapman, R. (2007). Effect of insulating existing houses on health inequality: cluster randomised study in the community. Bmj, 334 (7591), 460. Retrieved from https://doi.org/10.1136/bmj.39070.573032.80

[338] Reponen, T., Vesper, S., Levin, L., E., Ryan, P., Burkle, J,. Grinshpun, S., … LeMasters, G. (2011). High environmental relative moldiness index during infancy as a predictor of asthma at 7 years of age. *Annals of Allergy, Asthma & Immunology*, 107 (2), 120-126. DOI: http://dx.doi.org/10.1016/j.anai.2011.04.018

[339] Kercsmar, C., Dearborn, D., Schluchter, M., Xue, L., Kirchner, H.L., Sobolewski, J., Greenberg, S., Vesper S.J., Allan, T. (2006). Reduction in asthma morbidity in children as a result of home remediation aimed at moisture sources. *Environmental Health Perspectives*, 1574-1580. doi: 10.1289/ehp.8742

[340] Crocker, D., Kinyota, S., Dumitru, G., Ligon, C., Herman, E., Ferdinands, J., Hopkins, D., Lawrence, B., Sipe, T. and Task Force on Community Preventive Services. (2011). Effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity: a community guide systematic review. *American journal of preventive medicine*, 41 (2), S5-S32. Retrieved from https://doi.org/10.1016/j.amepre.2011.05.012

[341] Arbes, S., Sever, M., Mehta, J., Gore, J.C., Schal, C., Vaughn, B., Mitchell, H., Zeldin, D. (2004). Abatement of cockroach allergens (Bla g 1 and Bla g 2) in low-income, urban housing: month 12 continuation results. *Journal of Allergy and Clinical Immunology*, 113 (1), 109-114. Retrieved from https://doi.org/10.1016/j.jaci.2003.10.042

[342] Krieger, J., Jacobs, D. E., Ashley, P. J., Baeder, A., Chew, G. L., Dearborn, D., ... Zeldin, D. C. (2010). Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence. Journal of public health management and practice. *Journal of Public Health Management Practice, 16(5 Suppl).* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20689369

[343] U.S. Department of Energy. *Weatherization Program Notice 11-6.*

[344] Robert, J.W., Wallace, L.A., Camann, D.E., Dickey, P., Gilbert, S.G., Lewis, R.G., Takaro, T.K. (2009) Monitoring and Reducing Exposure of Infants to Pollutants in Housing Dust. *Reviews of Environmental Contamination and Toxicology 201.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19484587

[345] *Ibid.*

[346] Crocker, D., Kinyota, S., Dumitru, G., Ligon, C., Herman, E., Ferdinands, J., Hopkins, D., Lawrence, B., Sipe, T. and Task Force on Community Preventive Services. (2011). Effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity: a community guide systematic review. *American journal of preventive medicine*, 41 (2), S5-S32. Retrieved from https://doi.org/10.1016/j.amepre.2011.05.012

[347] Wang, C., Abou El-Nour, M., Bennett, G. (2008). Survey of pest infestation, asthma, and allergy in low-income housing. *Journal of community health*, 33 (1), 31-39. DOI 10.1007/s10900-007-9064-6

[348] Fritz, C., Fulhorst, C., Enge, B., Winthrop, K., Glaser, C., Vugia, D. (2002) Exposure to rodents and rodent-borne viruses among persons with elevated occupational risk. *Journal of occupational and environmental medicine*, 44 (10), 962-967. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12391776

[349] Holt, J., Davis, S., Leirs, H. (2006). A model of Leptospirosis infection in an African rodent to determine risk to humans: seasonal fluctuations and the impact of rodent control. *Acta tropica*, 99 (2), 218-225. Retrieved from https://doi.org/10.1016/j.actatropica.2006.08.003

[350] Dorevitch, S., Tharenos, L., Demirtas, H., Persky, V., Artwohl, J., Fortman, J. (2007). Inverse association between rural environment in infancy and sensitization to rodents in adulthood. *Annals of Allergy, Asthma & Immunology*, 98 (5), 440-446. DOI: http://dx.doi.org/10.1016/S1081-1206(10)60758-2

[351] Levine, J., Fritz, C., Novak., M. (2008). Occupational risk of exposure to rodent-borne hantavirus at US forest service facilities in California. *The American journal of tropical medicine and hygiene*, 78 (2), 352-357. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18256445

[352] Wang, C., Abou El-Nour, M., Bennett, G. (2008). Survey of pest infestation, asthma, and allergy in low-income housing. *Journal of community health*, 33 (1), 31-39. DOI 10.1007/s10900-007-9064-6

[353] Bragdon, C., Kass, D., Matte, T., Merlino, M., Bonaparte, S., Johnson S., Corriganc, R. (2012). Evaluation of a neighborhood rat-management program--New York City, December 2007-August 2009. *MMWR. Morbidity and mortality weekly report, 61*, 733-736. https://www.cdc.gov/mmwr/pdf/wk/mm6137.pdf

[354] Alp, H., Yu, B., Grant, E., Rao, V., Moy, J. (2001). Cockroach allergy appears early in life in inner-city children with recurrent wheezing. *Annals of Allergy, Asthma & Immunology*, 86 (1), 51-54. DOI: http://dx.doi.org/10.1016/S1081-1206(10)62355-1

[355] Gruchalla, R., Pongracic, J., Plaut, M., Evans, R., Visness, C., Walter, M., Crain, E., …Mitchell, H. (2005). Inner City Asthma Study: relationships among sensitivity, allergen exposure, and asthma morbidity. *Journal of Allergy and Clinical Immunology*, 115 (3), 78-485. DOI: 10.1016/j.jaci.2004.12.006

[356] Rabito, F., Carlson, J., Holt, E., Iqbal, S., James, M. (2011). Cockroach exposure independent of sensitization status and association with hospitalizations for asthma in inner-city children. *Annals of Allergy, Asthma & Immunology*, 106 (2), 103-109. https://doi.org/10.1016/j.anai.2010.10.013

[357] Donfack, J,. Tsalenko, A., Hoki, D., Parry, R., Solway, J., Lester, L., Ober, C. (2011). HLA-DRB1* 01 alleles are associated with sensitization to cockroach allergens. *Journal of allergy and clinical immunology*, 105 (5), 960-966. https://doi.org/10.1067/mai.2000.106926

[358] Roberts, J.W., Wallace, L.A., Camann, D.P., Dickey, P., Gilbert, S.G., Lewis, R.G., Takaro, T.K. (2009). Monitoring and reducing exposure of infants to pollutants in house dust. *Environmental Contamination and Toxicology, 201*, 1-39. Retrieved from DOI: 10.1007/978-1-4419-0032-6_1

[359] Wang, Z., Shalat, S.L., Black, K., Lioy, P.J., Stambler, A.A., Emoekpere O.H., Hernandez, M., Han, T., Ramagopal, M., Mainelis, G. (2012). Use of a robotic sampling platform to assess young children's exposure to indoor bioaerosols. *Indoor air*, 22 (2), 159-169. DOI: 10.1111/j.1600-0668.2011.00749.x

[360] Krieger, J., Jacobs, D., Ashley, P., Baeder, A., Chew, G., Dearborn, D., Hynes, H.P., Miller, J.D., Morley, R., Rabito, F., Zeldin, D. (2010) Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence. *Journal of public health management and practice*, 16(5). Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20689369

[361] *Ibid.*

[362] Wickens, K., Bruyne, J., Calvo, M., Choon-Kook, S., Jayaraj, G., Lai, C., Lane J., et al., … Crane, J. (2004). The determinants of dust mite allergen and its relationship to the prevalence of symptoms of asthma in the Asia-Pacific region. *Pediatric allergy and immunology*, 15 (1), 55-61. DOI: 10.1046/j.0905-6157.2003.00100.x

[363] Williams, A., Smith, J., Hudgens, E., Rhoney, S., Özkaynak, H., Hamilton, R., Gallagher, J. (2011). Allergens in household dust and serological indicators of atopy and sensitization in Detroit children with history-based evidence of asthma. *Journal of Asthma*, 48 (7), 674-684. DOI: 10.3109/02770903.2011.599909

[364] Woerden, H. (2004). Dust mites living in human lungs–the cause of asthma? *Medical hypotheses*, 63 (2), 193-197. Retrieved from https://doi.org/10.1016/j.mehy.2004.02.047

[365] Sheikh, A., Hurwitz, B., Shehata, Y. (2010). House dust mite avoidance measures for perennial allergic rhinitis. *Cochrane Database Syst Rev*, (7). DOI: 10.1002/14651858.CD001563.pub3

[366] Cingi, C., Cakli, H., Miman, O., Altin, F., Aycan, O., Atambay, M., and Daldal, N. (2007). Correlation of environmental mite levels & the symptoms of allergic rhinitis regarding the efficacy of preventive education. *Allergologia et immunopathologia*, 35 (6), 243-247. https://doi.org/10.1157/1311a,2990

[367] Kivity, S., Elbirt, D., Sade, K., Sthoeger, D., and Sthoeger, K. (2009). Efficacy of the Plasma Cluster device in asthmatic and/or allergic rhinitis patients with house dust mite allergy: a prospective observational pilot study. *The Israel Medical Association journal*:11 (2), 74-77. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19432033

[368] Lian, Y.Y., Liu, Z. G., Wang, H. Y., Chai, C. Y., and Liu, X. Y. (2007). Detection of mite allergens in the dust of filter-net and air of air-conditioned room. *Zhongguo ji sheng chong xue yu ji sheng chong bing za zhi= Chinese journal of parasitology & parasitic diseases*, 25 (4), 325-7. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18038805

[369] Mendell, M.J. (2004). Commentary: Air-conditioning as a risk for increased use of health services. *International Journal of Epidemiology*, 33(5), 1123-6. Retrieved from https://doi.org/10.1093/ije/dyh264

[370] Williams, A.H., Smith, J.T., Hudgens, E.E., Rhoney, S., Ozkaynak, H., Hamilton, R.G., Gallagher, J.E. (2011) Allergens in household dust and serological indicators of atopy and sensitization in Detroit children with history-based evidence of asthma. *Journal of Asthma, 48 (7), 674-84.* doi: 10.3109/02770903.2011.599909.

[371] Rao, D., Phipatanakul, W. Impact of environmental controls on childhood asthma. *Current allergy and asthma reports*, 11 (5), 414-420. Retrieved from https://doi.org/10.1007/s11882-011-0206-7

[372] *Ibid.*

[373] Kass, D., McKelvey, W., Carlton, E., Hernandez, M., Chew, G., Nagle, S., Garfinkel, R., Clarke, B., Tiven, J., Espino, C., Evans, D. (2009). Effectiveness of an Integrated Pest Management Intervention in Controlling Cockroaches, Mice, and Allergens in New York City Public Housing. *Environmental Health Perspective*, 117, 1219–1225. Retrieved from http://dx.doi.org/10.1289/ehp.0800149

[374] Ibid

[375] Pai, H., Hong, Y,. and Wang, C. (2003). A community-based surveillance on determinants of rodent infestation. *The Kaohsiung journal of medical sciences*, 19 (1), 13-17. Retrieved from https://doi.org/10.1016/S1607-551X(09)70442-5

[376] *Ibid.*

[377] Bragdon, C., Kass, D., Matte, T., Merlino, M., Bonaparte, S., Johnson S., Corriganc, R. (2012). Evaluation of a neighborhood rat-management program--New York City, December 2007-August 2009. *MMWR. Morbidity and mortality weekly report*, 61, 733-736. Retrieved from https://www.cdc.gov/mmwr/pdf/wk/mm6137.pdf

[378] de Masi, E,. Vilaça, P., and Razzolini, M.T. (2009). Environmental conditions and rodent infestation in Campo Limpo district, Sao Paulo municipality, Brazil. *International journal of environmental health research*, 19 (1), 1-16. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19241243

[379] Roomaney, R., Ehrlich, R., and Rother, H. (2012). The acceptability of rat trap use over pesticides for rodent control in two poor urban communities in South Africa. *Environmental Health*, 11 (1), 32. Retrieved from https://doi.org/10.1186/1476-069X-11-32

[380] McConnell, R., Jones, C., Milam, J., Gonzalez, P., Berhane, K., Clement, L., Richardson J., … Platts-Mills, T. (2003). Cockroach counts and house dust allergen concentrations after professional cockroach control and cleaning. *Annals of Allergy, Asthma & Immunology*, 91 (6), 546-552. DOI: http://dx.doi.org/10.1016/S1081-1206(10)61532-3

[381] Eggleston, P., Butz, A., Rand, C., Curtin-Brosnan, J., Kanchanaraksa, S., Swartz, L., Breysse P., … Krishnan, J. (2005). Home environmental intervention in inner-city asthma: a randomized controlled clinical trial. *Annals of Allergy, Asthma & Immunology*, 95 (6), 518-524. https://doi.org/10.1016/S1081-1206(10)61012-5

[382] Arshad, S. H., Bateman, B., and Matthews, S. M. (2003). Primary prevention of asthma and atopy during childhood by allergen avoidance in infancy: a randomised controlled study. *Thorax*, 58 (6) 489-493. http://dx.doi.org/10.1136/thorax.58.6.489

[383] Callahan, K.A., Eggleston, P.A., Rand, C.S., Kanchanaraksa, S., Swartz, L.J., and Wood, R.A. (2003). Knowledge and practice of dust mite control by specialty care. *Annals of Allergy, Asthma & Immunology*, 90 (3), 302-307. DOI: 10.1016/S1081-1206(10)61798-X

[384] Yoo, Y.S., Cho, O., Kim, E., and Jeong H. (2005). Effect of Asthma Management Education Program on Stress and Compliance of Patients with Allergic Asthma to House Dust Mite. *Journal of Korean Academy of Nursing*, 35 (4), 686-693. DOI: 10.4040/jkan.2005.35.4.686

[385] Vojta, P., Randels, S., Stout, J., Muilenberg, M., Burge, H., Lynn, H., Mitchell, H., O'Connor, G., and Zeldin, D. (2001). Effects of physical interventions on house dust mite allergen levels in carpet, bed, and upholstery dust in low-income, urban homes. *Environmental Health Perspectives*, 109 (8), 815-819. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11564617

[386] *Ibid.*

[387] Schei, M. A., Hessen, J. O. and Lund, E. (2002). House-dust mites and mattresses. *Allergy*, 57, 538–542. doi:10.1034/j.1398-9995.2002.23433.x

[388] Siebers, R. W., and Crane, J. (2011). Does bedding affect the airway and allergy? *The international journal of occupational and environmental medicine*, 2 (2). Retrieved from http://www.theijoem.com/ijoem/index.php/ijoem/article/view/68

[389] Matheson, M. C., Dharmage, S. C., Forbes, A. B., Raven, J. M., Woods, R. K., Thien, F. C. K., Guest, D. I., Rolland, J. M., Haydn Walters, E. and Abramson, M. J. (2003). Residential characteristics predict changes in Der p 1, Fel d 1 and ergosterol but not fungi over time. *Clinical & Experimental Allergy*, 33, 1281–1288. doi:10.1046/j.1365-2222.2003.01747.x

[390] Sheikh, A., Hurwitz, B., Shehata, Y. (2010). House dust mite avoidance measures for perennial allergic rhinitis. *Cochrane Database Syst Rev*, (7). DOI: 10.1002/14651858.CD001563.pub3

[391] Schei, M.A. (2002) House-dust mites and mattresses

[392] Brugge, D., Rioux, C., Groover, T., Peters, J., Kosheleva, A., Jonathan, I., Levy, J. (2007). Dust mites: Using Data from an Intervention Study to Suggest Future Research Needs and Directions. *Reviews on environmental health 22(3) 245-254.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18078006

[393] Warner, J., Fredrick, J., Bryant, T., Weich, C., Raw, C., Hunter, C., Stephen, F., ...Warner, J. (2000). Mechanical Ventilation and High-Efficiency Vacuum Cleaning: A Combined Strategy of Mite and Mite Allergen Reduction in the Control of Mite Sensitive Asthma. *The Journal of Allergy and Clinical Immunology 105(1 Pt 1)*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10629456#

[394] US Department of Energy, *Weatherization Program Notice* 11-6

[395] Akinbami, L., Moorman, J., Bailey, C., Zahran, H., King, M., Johnson, A., Liu, X. (2012). Trends in Asthma Prevalence, Health Care Use, and Mortality in the United States, 2001–2010. *NCHS Data Brief No. 94*. Retrieved from http://www.cdc.gov/nchs/data/databriefs/db94.pdf

[396] *Ibid.*

[397] *Ibid*

[398] Rabito, F., Carlson, J., Holt, E., Iqbal, S., James, A. (2011). Cockroach Exposure Independent of Sensitization Status and Association with Hospitalizations for Asthma in Inner-City Children. *Annals of Allergy, Asthma & Immunology*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21277511

[399] Gruchalla, R., Pongracic, J., Plaut, M., Evans, R., Visness, C., Walter, M., …Crain, E. (2005). Inner City Asthma Study: relationships among sensitivity, allergen exposure, and asthma morbidity. *Journal of Allergy and Clinical Immunology 115, no. 3,478-485*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15753892

[400] Institute of Medicine of the National Academies (2011). *Climate Change, the Indoor Environment, and Health*. Washington, D.C.: National Academies Press.

[401] Kenny, G., Yardley, J., Brown, C., Sigal, R., Jay O. (2010). Heat Stress in Older Individuals and Patients with Common Chronic Diseases. *Canadian Medical Association Journal, 182(10), 1053–1060*. doi:10.1503/cmaj.081050

[402] Zeka, A., Browne, S., McAvoy, H., Goodman, P. (2014). The Association of Cold Weather and All-Cause and Cause-Specific Mortality in the Island of Ireland Between 1984 and 2007. *Environmental Health, 13,104*. doi:10.1186/1476-069X-13-104

[403] Vardoulakis, S., Dear, K., Hajat, S., Heaviside, C., Eggen, B., McMichael, A. (2014) Comparative Assessment of the Effects of Climate Change on Heat- and Cold-Related Mortality in the United Kingdom and Australia. *Environmental Health Perspectives, 122(12), 1285–1292*. doi:10.1289/ehp.1307524

[404] Mendell, M., Lei-Gomez, Q., Mirer, A., Seppänen, O., Brunner, G. (2008). Risk Factors in Heating, Ventilating, and Air-Conditioning Systems For Occupant Symptoms in US Office Buildings: The US EPA BASE Study. I*ndoor air 18, no. 4, 301-316*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18492050

[405] Thompson, C. (2010). Negative Health Effects of Central Air Conditioning. Retrieved from: http://www.livestrong.com/article/160205-negative-health-effects-of-central-air-conditioning/

[406] *Ibid.*

[407] Institute of Medicine of the National Academies (2011). *Climate Change, the Indoor Environment, and Health*. Washington, D.C.: National Academies Press.

[408] Ibid

[409] Center for Disease Control and Prevention. (2016). *Legionnaires' Disease Fact Sheet* CS260481 Retrieved from http://www.cdc.gov/legionella/

[410] *Ibid.*

[411] *Ibid*, 188

[412] Harlan, S., Chowell, G., Yang, S., Pettit, D., Morales Butler, E., Benjamin, L., Ruddell, B., Ruddell, D. (2014). Heat-Related Deaths in Hot Cities: Estimates of Human Tolerance to High Temperature Thresholds. *International Journal of Environmental Research and Public Health 11, no. 3,3304-3326*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/24658410

[413] *Ibid.*

[414] Lindsay M. Howden and Julie A. Meyer. "Age and Sex Composition: 2010." *2010 Census Briefs* (May 2011) https://www.census.gov/prod/cen2010/briefs/c2010br-03.pdf

[415] Institute of Medicine of the National Academies (2011). *Climate Change, the Indoor Environment, and Health*. Washington, D.C.: National Academies Press.

[416] Kenny, G., Yardley, J., Brown, C., Sigal, R., Jay, O. (2010). Heat Stress in Older Individuals and Patients with Common Chronic Diseases. *Canadian Medical Association Journal, 182(10), 1053–1060*. Retrieved from doi:10.1503/cmaj.081050.

[417] Institute of Medicine of the National Academies (2011). *Climate Change, the Indoor Environment, and Health*. Washington, D.C.: National Academies Press.

[418] *Ibid.*

[419] Bouchama, A., Dehbi, M., Mohamed, G., Matthies, F., Shoukri, M., Menne, B. (2007). Prognostic Factors in Heat Wave–Related Deaths: A Meta-Analysis. *Archives of internal medicine,167, no. 20, 2170-2176*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17698676

[420] Lavigne, E., Gasparrini, A., Wang, X., Chen, H., Yagouti, A., Manon, D., Fleury, M., Cakmak, S. (2014). Extreme Ambient Temperatures and Cardiorespiratory Emergency Room Visits: Assessing Risk by Comorbid Health Conditions in a Time Series Study. *Environmental Health 13(5)*. Retrieved from https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-13-5

[421] *Ibid*, 7

[422] Medina-Ramón, M., & Schwartz, J. (2007). Temperature, Temperature Extremes, and Mortality: A study of Acclimatization and Effect Modification in 50 US cities. *Occupational and environmental medicine 64, no. 12,827-833*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17600037

[423] *Ibid*, 830

[424] Brandow, A., Stucky, C., Hillery, C., Hoffman, R., Panepinto, J. (2013). Patients with Sickle Celle Disease Have Increased Sensitivity to Cold and Heat. *American Journal of Hematology*, 88(1):37-43. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23115062

[425] McGeehin, M., & Mirabelli, M. (2001). The Potential Impacts of Climate Variability and Change on Temperature Related Morbidity and Mortality in the United States. *Environmental Health Perspectives*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240665/

[426] U.S. Department of Energy. *Weatherization Program Notice 11-6*

[427] Jesdale, B., Morello-Frosch, R., Cushing, L. (2013). The Racial/Ethnic Distribution of Heat Risk-Related Land Cover in Relation to Residential Segregation. *Environmental Health Perspectives*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3701995/

[428] Bassil, K., & Cole, D. (2010). Effectiveness of Public Health Interventions in Reducing Morbidity and Mortality During Heat Episodes: A Structured Review. *International journal of environmental research and public health 7, no. 3,991-1001*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2872323/

[429] *Ibid*.

[430] Tonn, B., Rose, E., Hawkins, B., Conlon, B., (2014). Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. *National Evaluation of the Department of Energy's Weatherization Assistant Program*. Retrieved from http://weatherization.ornl.gov/Retrospectivepdfs/ORNL_TM-2014_345.pdf

[431] Tonn, B., Rose, E., Hawkins, B., Conlon, B. (2015). Evaluating the health benefits of weatherization. *Oak Ridge National Laboratory and Three3, Inc*. International Energy Agency Workshop Presentation. Retrieved from https://www.iea.org/media/workshops/2015/eeuevents/mb2004/S2Bruce_Tonn.pdf

[432] Pigg, S., Cautley, D., Franciscon, P., Hawkins, B., Brennan, T., (2014). Weatherization and Indoor Air Quality: Measured Impacts in Single-Family Homes under the Weatherization Assistance Program. *Oak Ridge National Laboratory*. Retrieved from http://weatherization.ornl.gov/Retrospectivepdfs/ORNL_TM-2014_170.pdf

[433] *Ibid*

[434] Tonn, B., et al. (2015). Evaluating Health Benefits of Weatherization.

[435] McGeehin, M., & Mirabelli, M. (2001). The Potential Impacts of Climate Variability and Change on Temperature-Related Morbidity and Mortality in the United States. *Environmental health perspectives 109, no. Suppl 2,185*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240665/

[436] Greene, S., Kalkstein, L., Mills, D., Samenow, J. (2011) An Examination of Climate Change on Extreme Heat Events and Climate–Mortality Relationships in Large U.S. Cities. *Weather, Climate and Society, 3, 281–292*. Retrieved from doi: http://dx.doi.org/10.1175/WCAS-D-11-00055.1

[437] Tonn, B., Carroll, D., Rose, E., Hawkins, B., Pigg, S., Bausch, D., …Dalhoff, G. (2015). Weatherization Works II: ARRA Period Evaluation of the US Department of Energy's Weatherization Assistance Program. *Oak Ridge National Laboratory*. Retrieved from https://energy.gov/sites/prod/files/2015/09/f26/weatherization-works-II-ARRA-period-eval.pdf

[438] Tonn, B., et al. (2015). Evaluating Health Benefits of Weatherization.

[439] *Ibid*.

[440] Hernández, D. (2013). Energy Insecurity a Framework for Understanding Energy, the Built Environment, and Health Among Vulnerable Populations in the Context of Climate change. *American Journal of Public Health, 103(4)*, e32-e34. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3673265/

[441] Tonn, B., et al. (2015). Weatherization Works II.

[442] Tonn, B., et al. (2015). Evaluating Health Benefits of Weatherization.

[443] O'Neill, M., Zanobetti, A., Schwartz, J. (2005). Disparities by Race in Heat-Related Mortality in Four US cities: The Role of Air Conditioning Prevalence. *Journal of Urban Health 82, no. 2,191-197*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15888640

[444] Ostro, B., Rauch, S., Green, S. (2011). Quantifying the Health Impacts of Future Changes in Temperature in California. *Environmental Research,111(8)*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21975126

[445] World Health Organization. (2017). Unintentional Childhood Injuries: Children's Health and the Environment. *WHO Training Package for the Health Sector World Health Organization*. Retrieved from www.who.int/ceh

[446] Mack, K., Rudd, R., Mickalide, A., Ballesteros, M. (2013). Fatal Unintentional Injuries in the Home in the U.S., 2000–2008. *American Journal of Preventive Medicine,44:239–246*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23415120

[447] Mack, K. A., Rudd, R. A., Mickalide, A. D., & Ballesteros, M. F. (2013). Fatal Unintentional Injuries in the Home in the U.S., 2000–2008. *American Journal of Preventive Medicine*, 44(3), 239–246. Retrieved from http://doi.org/10.1016/j.amepre.2012.10.022

[448] Healthy People 2020. (2017). Retrieved from https://www.healthypeople.gov/2020/topics-objectives/topic/injury-and-violence-prevention#7

[449] Runyan, C.W., Casteel, C., Perkis, D., Black C., Marshall. S.W., Johnson, R.M., & Viswanathan, S. (2005). Unintentional injuries in the home in the United States Part I: Mortality. *American Journal of Preventive Medicine*. 28:73–79. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15626560

[450] Mack, K.A., Rudd, R.A., Mickalide, A.D., & Ballesteros, M.F. (2013). Fatal unintentional injuries in the home in the U.S., 2000–2008. *American Journal of Preventive Medicine*. 44:239–246. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23415120

[451] Runyan, C.W., Perkis, D., Marshall, S.W., Johnson, R.M., Coyne-Beasley, T., Waller, A.E., & Baccaglini, L. Unintentional injuries in the home in the United States Part II: Morbidity. *American Journal of Preventive Medicine*. 2005; 28:80–87. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15626561

[452] Mack, K.A., Liller, K.D., Baldwin, G., & Sleet, D. (2015). Preventing Unintentional Injuries in the Home Using the Health Impact Pyramid. *Health Education & Behavior: The Official Publication of the Society for Public Health Education*, 42(1 0), 115S–122S. Retrieved from http://doi.org/10.1177/1090198114568306

[453] Healthy People 2020. (2017). Retrieved from https://www.healthypeople.gov/2020/topics-objectives/topic/injury-and-violence-prevention#7; Centers for Disease Control and Prevention. (2017) Injury Prevention. Retrieved from https://www.cdc.gov/healthyhomes/bytopic/injury.html

[454] World Health Organization. (2017). Unintentional Childhood Injuries. Children's Health and the Environment. *WHO Training Package for the Health Sector World Health Organization*. Retrieved from www.who.int/ceh

[455] Mack, K.A., Liller, K.D., Baldwin, G., & Sleet, D. (2015). Preventing Unintentional Injuries in the Home Using the Health Impact Pyramid. *Health Education & Behavior: The Official Publication of the Society for Public Health Education, 42*(10), 115S–122S. Retrieved from http://doi.org/10.1177/1090198114568306

[456] Phelan, K.J., Khoury, J., Xu, Y., Liddy, S., Hornung, R., & Lanphear, B.P. (2011) A randomized controlled trial of home injury hazard reduction: the HOME injury study. *Injury Prevention 16 Suppl: A171*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21464382

[457] Mack, K.A., Liller, K.D., Baldwin, G., & Sleet, D. (2015). Preventing Unintentional Injuries in the Home Using the Health Impact Pyramid. *Health Education & Behavior: The Official Publication of the Society for Public Health Education, 42(10)*, 115S–122S. Retrieved from http://doi.org/10.1177/1090198114568306

[458] Gillespie, L.D., Robertson, M.C., Gillespie, W.J., Sherrington, C., Gates, S., Clemson, L.M., & Lamb, S.E. (2012) Interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews (9). Art. No.: CD007146*. Retrieved from DOI: 10.1002/14651858.CD007146.pub3.

Lamb, S.E., Jorstad-Stein, E.C., Hauer, K., & Becker, C. (2005). Development of a common outcome data set for fall injury prevention trials: The Prevention of Falls Network Europe consensus. *Journal of the American Geriatrics Society* 53(9):1618–22. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16137297

[459] Mack, K. A., Rudd, R. A., Mickalide, A. D., & Ballesteros, M. F. (2013). Fatal Unintentional Injuries in the Home in the U.S., 2000–2008. *American Journal of Preventive Medicine, 44*(3), 239–246. Retrieved from http://doi.org/10.1016/j.amepre.2012.10.022

[460] Gillespie, L.D., Robertson, M.C., Gillespie, W.J., Sherrington, C., Gates, S., Clemson, L.M., & Lamb, S.E. (2012) Interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews (9). Art. No.: CD007146*. Retrieved from DOI: 10.1002/14651858.CD007146.pub3.

[461] Centers for Disease Control and Prevention (2017). Costs of falls among older adults. Retrieved from https://www.cdc.gov/homeandrecreationalsafety/falls/fallcost.html

[462] Alexander, B.H., Rivara, F.P., Wolf, M.E. (1992). The cost and frequency of hospitalization for fall–related injuries in older adults. *American Journal of Public Health 82(7):1020–3*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/1609903;

Sterling, D.A., O'Connor, J.A., Bonadies, J. (2001). Geriatric falls: injury severity is high and disproportionate to mechanism. *Journal of Trauma–Injury, Infection and Critical Care* 50(1):116–9. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11231681

[463] Hayes, W.C., Myers, E.R., Morris, J.N., Gerhart, T.N., Yett, H.S., Lipsitz, L.A. (1993). Impact near the hip dominates fracture risk in elderly nursing home residents who fall. *Calcified Tissue International; 52: 192-198*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/8481831

[464] Parkkari, J., Kannus, P., Palvanen, M., Natri, A., Vainio, J., Aho, H, Vuori I, Järvinen M. (1999). Majority of hip fractures occur as a result of a fall and impact on the greater trochanter of the femur: a prospective controlled hip fracture study with 206 consecutive patients. *Calcified Tissue International; 65:183–7*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10441647

[465] Jager, T.E., Weiss, H.B., Coben, J.H., Pepe, P.E. (2000). Traumatic brain injuries evaluated in U.S. emergency departments, 1992–1994. *Academic Emergency Medicine* 7(2):134–40. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10691071

[466] Centers for Disease Control and Prevention. (2017). Risk Factors for Falls. Retrieved from https://www.cdc.gov/steadi/pdf/risk_factors_for_falls-a.pdf

[467] Centers for Disease Control and Prevention. (2016). National Action Plan for Child Injury Prevention. Retrieved from https://www.cdc.gov/safechild/nap/

[468] Centers for Disease Control and Prevention. (2016). National Action Plan for Child Injury Prevention. Retrieved from https://www.cdc.gov/safechild/pdf/national_action_plan_for_child_injury_prevention.pdf

[469] Kendrick, D., Young, B., Mason-Jones, A.J., Ilyas, N., Achana, F.A., Cooper, N.J., Hubbard, S.J., Sutton, A.J., Smith, S., Wynn, P., Mulvaney, C., Watson, M.C., & Coupland, C. (2012). Home safety education and provision of safety equipment for injury prevention. *Cochrane Database of Systematic Reviews* Issue 9. Art. No.: CD005014. Retrieved from DOI: 10.1002/14651858.CD005014.pub3

[470] Healthy People 2020. (2014). Maternal, Infant, and Child Health. Retrieved from https://www.healthypeople.gov/2020/leading-health-indicators/2020-lhi-topics/Maternal-Infant-and-Child-Health/data?source=govdelivery&utm_medium=e-mail&utm_source=govdelivery

[471] Centers for Disease Control and Prevention. (2012). Child Injury Infographic. Retrieved from https://www.cdc.gov/vitalsigns/childinjury/infographic.html

[472] Centers for Disease Control and Prevention. (2017). Infant Health. Retrieved from https://www.cdc.gov/chronicdisease/resources/publications/aag/infant-health.htm

[473] Kendrick, D., Young, B., Mason-Jones, A.J., Ilyas, N., Achana, F.A., Cooper, N.J., Hubbard, S.J., Sutton, A.J., Smith, S., Wynn, P., Mulvaney, C., Watson, M.C., & Coupland, C. (2012). Home safety education and provision of safety equipment for injury prevention. *Cochrane Database of Systematic Reviews*, Issue 9. Art. No.: CD005014. Retrieved from DOI: 10.1002/14651858.CD005014.pub3.

[474] *Ibid*

[475] *Ibid*

[476] Gillespie, L.D., Robertson, M.C., Gillespie, W.J., Sherrington, C., Gates, S., Clemson, L.M., & Lamb, S.E. (2012). Interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews* Sep 12;(9). Retrieved from CD007146.http://doi:10.1002/14651858.CD007146.pub3.

[477] *Ibid*

[478] Ibid

[479] Mack, K.A., Rudd, R.A., Mickalide, A.D., & Ballesteros, M. F. (2013). Fatal Unintentional Injuries in the Home in the U.S., 2000–2008. *American Journal of Preventive Medicine, 44*(3), 239–246. Retrieved from http://doi.org/10.1016/j.amepre.2012.10.022

[480] Kendrick, D., Young, B., Mason-Jones, A.J., Ilyas, N., Achana, F.A., Cooper, N.J., Hubbard, S.J., Sutton, A.J., Smith, S., Wynn, P., Mulvaney, C., Watson, M.C., & Coupland, C. (2012). Home safety education and provision of safety equipment for injury prevention. *Cochrane Database of Systematic Reviews*, Issue 9. Art. No.: CD005014. Retrieved from DOI: 10.1002/14651858.CD005014.pub3.

[481] Gillespie, L.D., Robertson, M.C., Gillespie, W.J., Sherrington, C., Gates, S., Clemson, L.M., & Lamb, S.E. (2012). Interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews* Sep 12;(9). Retrieved from CD007146.http://doi:10.1002/14651858.CD007146.pub3.

[482] Turner, S., Arthur, G., Lyons, R.A., Weightman, A.L., Mann, M.K., Jones, S.J., Lannon, S. (2011). Modification of the home environment for the reduction of injuries. Cochrane Database of Systematic Reviews. (2): CD003600 Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21328262

[483] Centers for Disease Control and Prevention. (2016). Cost of Injury. Retrieved from https://www.cdc.gov/injury/wisqars/overview/cost_of_injury.html

[484] Haegerich, T.M., Dahlberg, L.L., Simon, T.R., Baldwin, G.T., Sleet, D.A., & Greenspan, A.I. (2014). Prevention of Injury and Violence in the USA. *The Lancet* 384(9937), 64–74. Retrieved from http://doi.org/10.1016/S0140-6736(14)60074-X

Miller, T.R., Finkelstein, A.E., Zaloshnja, E., Hendrie, D. (2012). The cost of child and adolescent injuries and the savings from prevention. *Injury prevention for children and adolescents: research, practice, and advocacy. American Public Health Association*. Retrieved from http://ajph.aphapublications.org/doi/abs/10.2105/9780875530055ch02

[485] Haegerich, T.M., Dahlberg, L.L., Simon, T.R., Baldwin, G.T., Sleet, D.A., & Greenspan, A.I. (2014). Prevention of Injury and Violence in the USA. *The Lancet* 384(9937), 64–74. Retrieved from http://doi.org/10.1016/S0140-6736(14)60074-X

Carande-Kulis, V.G., Stevens, J., Beattie, B.L., Arias, I. (2010). The business case for interventions to prevent fall injuries in older adults. Injury Prevention. 16(supplement 1): A249. Retrieved from http://injuryprevention.bmj.com/content/16/Suppl_1/A249.2

[486] Burns, E.B., Stevens, J.A., Lee, R.L. (2016). The direct costs of fatal and non-fatal falls among older adults—United States. *Journal of Safety Research* 58. Retrieved from https://www.cdc.gov/media/releases/2016/p0922-older-adult-falls.html

[487] Ibid

[488] Gillespie, L.D., et al. (2012). Interventions for preventing falls in older people living in the community.

[489] Centers for Disease Control and Prevention (2016). Web–based Injury Statistics Query and Reporting System. Retrieved from https://www.cdc.gov/injury/wisqars/index.html

[490] Healthy People 2020. (2016). Injury and Violence Prevention. Retrieved from https://www.healthypeople.gov/2020/topics-objectives/topic/injury-and-violence-prevention#3

Florence, C., Simon, T., Haegerich, T., Luo, F., & Zhou, C. (2015). Estimated lifetime medical and work-loss costs of fatal injuries-United States, 2013. *MMWR: Morbidity and mortality weekly report, 64(38), 1074-1077*. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6438a4.htm

Florence, C., Haegerich, T., Simon, T., Zhou, C., & Luo, F. (2015). Estimated lifetime medical and work-loss costs of emergency department-treated nonfatal injuries-United States, 2013. *MMWR: Morbidity and mortality weekly report, 64(38), 1078-1082*. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6438a5.htm

[491] Florence, C., Simon, T., Haegerich, T., Luo, F., & Zhou, C. (2015). Estimated lifetime medical and work-loss costs of fatal injuries-United States, 2013. *MMWR: Morbidity and mortality weekly report, 64(38), 1074-1077*. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6438a4.htm

[492] Florence, C., Haegerich, T., Simon, T., et al. (2015). Estimated lifetime medical and work-loss costs of emergency department–treated nonfatal injuries—United States, 2013. *MMWR: Morbidity and Mortal Weekly Report; 64:1078–82*. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6438a5.htm

[493] National Safety Council. (2003). *Injury Fact: 2003 Edition*. Itasca, IL: National Safety Council.

[494] *Ibid*.

[495] DiGuiseppi, C. et.al. (2010). Housing interventions and control of injury-related structural deficiencies.

[496] Gielen, A., Shields, W., Frattaroli, S., McDonald, E., Jones, V., Bishai, D.,...O'Brocki, R. (2012). Enhancing Fire Department Home Visiting Programs: Results of a Community Intervention Trial. *Journal of burn care & research: Official Publication of the American Burn Association,34, no. 4,e250-6*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23237821

[497] Mack, K.A., Liller, K.D., Baldwin, G., & Sleet, D. (2015). Preventing Unintentional Injuries in the Home Using the Health Impact Pyramid. *Health Education & Behavior: The Official Publication of the Society for Public Health Education*, 42(10), 115S–122S. Retrieved from http://doi.org/10.1177/1090198114568306

[498] Ibid

[499] US Fire Administration. (2014). Residential Fires 2011-2013. *Topical Fire Report Series* 16(1). Retrieved from https://nfa.usfa.fema.gov/downloads/pdf/statistics/v16i3.pdf

[500] Hall, JR. (1997). Burns, toxic gases, and other hazards associated with fires: deaths and injuries in fire and non-fire situations. *The National Fire Protection Association*. Retrieved from http://www.cdc.gov/ncipc/factsheets/fire.htm.

[501] National Safety Council. (2003). Injury Fact: 2003 Edition. Itasca, IL: National Safety Council.

[502] DiGuiseppi, C. et.al. (2010). Housing interventions and control of injury-related structural deficiencies.

[503] Gyllensvärd, H. (2010). Cost-Effectiveness of Injury Prevention-a Systematic Review of Municipality Based Interventions. *Cost Effective Resource Allocation 8,17*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2945985/

[504] Haddix, A., Mallonee, S., Waxweiler, R., Douglas, M. (2001). Cost Effectiveness Analysis of a Smoke Alarm Giveaway Program in Oklahoma City, Oklahoma. *Injury Prevention 7, no. 4, 276-281*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11770651

[505] DiGuiseppi, C. et.al. (2010). Housing interventions and control of injury-related structural deficiencies.

[506] Gielen.A. (2014). Enhancing Fire Department Home Visiting Programs.

[507] Arai, L., Roen, K., Roberts, K., Popay, J. (2005). It Might Work in Oklahoma but Will it Work in Oakhampton? Context and Implementation in the Effectiveness Literature on Domestic Smoke Detectors. *Injury Prevention 11, no.148-151*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1730217/

[508] Gielen.A. (2014). Enhancing Fire Department Home Visiting Programs.

[509] *Ibid*.

[510] Ahrens, M. (1998). US Experience with Smoke Alarms and Other Fire Alarms: Who Has Them?: How Well Do They Work?: When Don't They Work?. *National Fire Protection Association*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10137381

[511] *Ibid*.

[512] Deave, T., Goodenough, T., Stewart, J., Towner, E., Majsak-Newman, G., Hawkins, A., Coupland, C., & Kendrick, D. (2013). Contemporary Hazards in the Home: Keeping Children Safe From Thermal Injuries. *Archives of Disease in Childhood*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23592729

[513] *Ibid.*

[514] Charters, D. (2012). Getting Fire Risk Assessment Right. *Health Estate 66, no. 6,40-42*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22764626

[515] Centers for Disease Control and Prevention (2011). Carbon Monoxide Exposures. *Morbidity and Mortality Weekly Reports, United States,2000-2009*. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6030a2.htm

[516] Cooper, N., Kendrick, D., Achana, F., Dhiman, P., He, Z., Wynn, P., Sutton, A. (2012). Network Meta-Analysis to Evaluate the Effectiveness of Interventions to Increase the Uptake of Smoke Alarms. *Epidemiologic Reviews 34, no,32-45*. Retrieved from https://academic.oup.com/epirev/article/34/1/32/492847

[517] *Ibid.*

[518] Diekman, S., Huitric, M., Netterville, L. (2010). The Development of the Residential Fire HELP Tool Kit: A Resource to Protect Homebound Older Adults. *Journal of Public Health Management and Practice 16, no. 5,S61-S67*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20689377

[519] Papanikolaou, N., Hatzidaki, E. Belivanis, S., Tzanakakis, G., Tsatsakis, A. (2005). Lead Toxicity Update. A Brief Review. *Medical Science Monitor 11, no. 10,RA329-RA336*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16192916

[520] Jacobs, D., Clickner, R., Zhou, J., Viet, S., Marker, D., Rogers, J., Friedman, W. (2002). The Prevalence of Lead-Based Paint Hazards in US Housing. *Environmental health perspectives,110, no. 10, A599*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241046/

[521] Centers for Disease Control and Prevention. (2013). Blood lead levels in children aged 1-5 years-United States, 1999-2010. MMWR. *Morbidity and mortality weekly report* 62(13): 245. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6213a3.htm

[522] Papanikolaou, N. (2005). Lead toxicity update.

[523] *Ibid.*

[524] *Ibid.*

[525] *Ibid.*

[526] *Ibid.*

[527] *Ibid.*

[528] *Ibid.*

[529] *Ibid.*

[530] *Ibid.*

[531] Dietrich, K., Douglas, R., Succop, P., Berger, O., Bornschein, R. (2001). Early Exposure to Lead and Juvenile Delinquency. *Neurotoxicology and Teratology 23, no. 6,51*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11792521

[532] *Ibid.*

[533] Clark, S., Galke, W., Succop, P., Grote, J., McLaine, P., Wilson, J., Dixon.S., …& Jacobs, D. (2011). Effects of HUD-Supported Lead Hazard Control Interventions in Housing on Children's Blood lead. *Environmental research 111, no. 2 (2011): 301-311*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21183164

[534] *Ibid.*

[535] *Ibid.*

[536] *Ibid.*

[537] *Ibid.*

[538] *Ibid.*

[539] Dixon, S., Jacobs, D., Wilson, J., Akoto, J., Nevin, R., Scott Clark, S. (2012). Window Replacement and Residential Lead Paint Hazard Control 12 Years Later. *Environmental research,113, 14-20*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22325333

[540] *Ibid.*

[541] *Ibid.*

[542] *Ibid.*

[543] *Ibid.*

[544] *Ibid.*

[545] *Ibid.*

[546] *Ibid.*

[547] *Ibid.*

[548] Dixon, S. (2012). Window Replacement and Residential Lead Paint Hazard Control 12 Years Later

[549] *Ibid*, 19

[550] Gould, E. (2009). Childhood Lead Poisoning: Conservative Estimates of the Social and Economic Benefits of Lead Hazard Control. *Environmental Health Perspectives, 117, no. 7, 1162-1167*. Retrieved from https://ehp.niehs.nih.gov/0800408/

[551] Adler, T. (2009). A Lucrative Investment: Controlling Lead Paint Yields Big Dividends. *Environmental health perspectives,117, no. 7,A311*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2717163/

[552] Gould, E. (2009). Childhood Lead Poisoning: Conservative Estimates of the Social and Economic Benefits of Lead Hazard Control.

[553] *Ibid.*

[554] Adler, T. (2009). A Lucrative Investment: Controlling Lead Paint Yields Big Dividends.

[555] Gould, E. (2009). Childhood Lead Poisoning: Conservative Estimates of the Social and Economic Benefits of Lead Hazard Control.

[556] *Ibid.*

[557] *Ibid.*

[558] Van der Vlist, A., Gorter, C., Nijkamp, P., Rietveld, P. (2002). Residential Mobility and Local Housing Market Differences. Timbergen Institute. Retrieved from http://journals.sagepub.com/doi/abs/10.1068/a34176

[559] Ok Lee, K. (2012). Residential Relocation Decisions: The Role of Neighborhood Housing Characteristics. *Institute of Real Estate Studies.*

[560] United States Census. (2012). Historical Census of Housing Tables: Home Values. Retrieved from https://www.census.gov/hhes/www/housing/census/historic/values.html

[561] Ibid

[562] How Housing Matters Press Release.(2016).Pessimism about Prolonged Housing Affordability Crisis is On the Rise. *2016 How Housing Matters Survey Finds.* Retrieved from https://www.macfound.org/press/press-releases/pessimism-about-prolonged-affordable-housing-crisis-rise-2016-how-housing-matters-survey-finds/

[563] Kain, J., Quigley, J. (1970). Measuring the Value of Housing Quality. *Journal of the American Statistical Association.* Retrieved from http://urbanpolicy.berkeley.edu/pdf/kq_jasa70.pdf

[564] Parasuraman, A., Zeithml, V., Berry, L. (1985). A Conceptual Model of Service Quality and Its Implications for Future Research. *The Journal of Marketing.* 49(4). Retrieved from https://www.jstor.org/stable/1251430?seq=1#page_scan_tab_contents

[565] Easton, R. (1993). The Consequences of Quality: The Effects of Customer Satisfaction on Tenant Retention. *Massachusetts Institute of Technology Master's Thesis.* Retrieved from https://dspace.mit.edu/bitstream/handle/1721.1/65690/30056515-MIT.pdf?sequence=2

[566] Rental Protection Agency. (2017). 10 Most Common Apartment Complaints by Tenants. Retrieved from https://www.american-apartment-owners-association.org/property-management/latest-news/10-most-common-apartment-complaints/

[567] Dong, M., Anda, R., & Felitti, V. (2005). Childhood Residential Mobility and Multiple Health Risks During Adolescence and Adulthood: The Hidden Rold of Adverse Childhood Experiences. *Archives of Pediatrics & Adolescent Medicine 159(12.)* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16330731

[568] Rumberger, R. & Larson, K. (1998). Student Mobility and the Increased Risk of High School Dropout. *American Journal of Education.* 107(1). Retrieved from https://www.jstor.org/stable/1085729

[569] Simpson, R.J. (1998). Local Friendship Ties and Community Attachment in Mass Society: A Multilevel Systemic Model. *American Sociological Review.* 53(5) Retrieved from https://scholar.harvard.edu/files/sampson/files/1988_asr.pdf

[570] Sandel, M., & Wright, R. (2006). When Home is Where the Stress is: Expanding the Dimensions of Housing that Influence *Asthma Morbidity. Archives of Disease in Childhood, 91, no. 11,942-948.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17056870

[571] *Ibid.*

[572] Joydeep, R., Maynard, M., & Weiss, E. (2008). The Hidden Costs of the Housing Crisis: The Long-Term Impact of Housing Affordability and Quality on Young Children's Odds of Success. *Partnership for America's Economic Success.* Retrieved from http://www.pewtrusts.org/~/media/legacy/uploadedfiles/wwwpewtrustsorg/reports/partnership_for_americas_economic_success/paeshousingreportfinal1pdf.pdf

[573] Center on the Developing Child. (2014). Key Concepts: Toxic Stress. *Harvard University*. Retrieved from http://developingchild.harvard.edu/science/key-concepts/toxic-stress/

[574] Roman, C., & Knight, C. (2010). An Examination of the Social and Physical Environment of Public Housing Residents in Two Chicago Developments in Transition. *The Urban Institute*. Retrieved from https://www.urban.org/sites/default/files/publication/28816/412134-An-Examination-of-the-Social-and-Physical-Environment-of-Public-Housing-Residents-in-Two-Chicago-Developments-in-Transition.PDF

[575] *Ibid*.

[576] Sandel, M., & Wright, R. (2006). When Home is Where the Stress is: Expanding the Dimensions of Housing that Influence Asthma Morbidity. *Archives of Disease in Childhood, 91, no. 11,942-948*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/17056870

[577] Gifford, R., & Lacombe, C. (2006). Housing quality and children's socioemotional health. *Journal of Housing and the Built Environment*. 21(2). Retrieved from https://www.jstor.org/stable/41107338?seq=1#page_scan_tab_contents

[578] *Ibid*.

[579] Saxena, S., Jané-Llopis, E., & Hosman, C. (2006). Prevention of Mental and Behavioural Disorders: Implications for Policy and Practice. *World Psychiatry 5, no. 1-5*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1472261/

[580] Roman, C., & Knight, C. (2010). An Examination of the Social and Physical Environment of Public Housing Residents in Two Chicago Developments in Transition. *The Urban Institute*. Retrieved from https://www.urban.org/sites/default/files/publication/28816/412134-An-Examination-of-the-Social-and-Physical-Environment-of-Public-Housing-Residents-in-Two-Chicago-Developments-in-Transition.PDF

[581] Galea, S., Ahern, J., Rudenstine, S., Wallace, R., Vlahov, D. (2005). Urban Built Environment and Depression: A Multilevel Analysis. *Journal of Epidemiology and Community Health 59(10) 822-827*. Retrieved from http://jech.bmj.com/content/59/10/822

[582] Liddell, C., & Morris, C. (2010). Fuel Poverty and Human Health: A Review of Recent Evidence. *Energy policy 38, no. 6,2987-2997*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0301421510000625

[583] *Ibid*.

[584] *Ibid*.

[585] Tonn, B., et al. (2014). Health and Household-Related Benefits Attributable to the Weatherization Assistance Program.

[586] *Ibid*, 11

[587] *Ibid*

[588] Braubach, M., Heinen.D., Dame, J. (2007). Preliminary Results of the WHO Frankfurt Housing Intervention Project. *World Health Organization*. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0011/98696/E91699.pdf

[589] *Ibid*.

[590] Grant, R., & Brito, A (2010). Chronic Illness and School Performance: A Literature Review Focusing on Asthma and Mental Health Conditions. *A Children's Health Fund Monograph*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.459.792&rep=rep1&type=pdf

[591] Papanikolaou, N., et al. (2005). Lead toxicity update.

[592] Ferguson, K., Cassells, R., MacAllister, J., Evans, G. (2013). The Physical Environment and Child Development: An International Review. *International Journal of Psychology 48, no. 4,437-468*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4489931/

[593] *Ibid*.

[594] Evens, A., Hryhorczuk, D., Lanphear, B., Rankin, K., Lewis, D., Forst, L., Rosenberg, D. (2015).The Impact of Low-Level Lead Toxicity on School Performance Among Children in the Chicago Public Schools: A Population-Based Retrospective Cohort Study. *Environmental Health 14, no. 1,21*. Retrieved from https://ehjournal.biomedcentral.com/articles/10.1186/s12940-015-0008-9

[595] Needleman, H., Schell, A., Bellinger, D., Leviton, A., Allred, E. (1990). The Long-Term Effects of Exposure to Low Doses of Lead in Childhood: An 11-Year Follow-up Report. *New England Journal of Medicine,322, no. 2,83-88*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/2294437

[596] Tarr, H., Raymond, R., Tufts, M. (2009). The Effects of Lead Exposure on School Outcome Among Children Living and Attending Public Schools in Detroit, MI. *Department of Health and Wellness Promotion. Detroit, Detroit Public Schools*. Retrieved from https://www.edweek.org/media/detroitlead.pdf

[597] Ferguson, K., Cassells, R., MacAllister, J., Evans, G. (2013). The Physical Environment and Child Development: An International Review. *International Journal of Psychology. 48(4)*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4489931/

[598] *Ibid.*

[599] *Ibid.*

[600] Akinbami, L., Moorman, J., Bailey, C., Zahran, H., King, M., Johnson, C., & Liu, X. (2012). Trends in Asthma Prevalence, Health Care Use, and Mortality in the United States, 2001–2010. *National Center for Health Statistics Data Brief (94):1-8*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22617340

[601] Esteban, C et al. (2014). Underdiagnosed and Undertreated Allergic Rhinitis in Urban School-Aged Children with Asthma. *Pediatric Allergy, Immunology, and Pulmonology*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/24963455

[602] Grant, R. & Brito, A. (2010). Chronic Illness and School Performance. *Children's Health Fund.*

[603] *Ibid.*

[604] Stingone, J., & Claudio, L. (2006). Asthma and Enrollment in Special Education among Urban Schoolchildren. *American Journal of Public Health 96(9)*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1551960/

[605] *Ibid.*

[606] *Ibid.*

[607] Levine, J., Fritz, C., Novak, M. (2008). Occupational Risk of Exposure to Rodent-Borne Hantavirus at US Forest Service Facilities in California. *The American Journal of Tropical Medicine and Hygiene, 78, no. 2,352-357*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18256445

[608] Fisk, W., & Seppanen, O. (2007). Providing Better Indoor Environmental Quality Brings Economic Benefits. *Lawrence Berkeley National Laboratory*. Retrieved from http://immobilierdurable.eu/images/2128_uploads/b_n_fices__co_et_confort_DK_.pdf

[609] *Ibid.*

[610] Warner, J., Fredrick, J., Bryant, T., Weich, C., Raw, C., Hunter, C., Stephen, F., ...Warner, J. (2000). Mechanical Ventilation and High-Efficiency Vacuum Cleaning: A Combined Strategy of Mite and Mite Allergen Reduction in the Control of Mite Sensitive Asthma. *Journal of Allergy and Clinical Immunology 105(1 Pt 1)*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/10629456

[611] Mendell, M., Eliseeva, E., Davies, M., Spears, M., Lobscheid, A., Fisk, W., & Apte, M. (2013). Association of Classroom Ventilation With Reduced Illness Absence: A Prospective Study in California Elementary Schools. *Indoor air 23(6), 515-528*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/23506393

[612] Dirks, J., Anderson, D., Hostick, D., Belzer, D., & Cort, K. (2008). Lost Opportunities in the Buildings Sector: Energy-Efficiency Analysis and Results. *Pacific Northwest National Laboratory (PNNL), PNNL-17623*. Retrieved from http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17623.pdf

[613] Busche, S., Doris, E., Braccio, D., Lippert, P., Finch, D., & Fetter, J. (2010). Clean Energy Policy Analysis: Impact Analysis of Potential Clean Energy Policy Options for the Hawaii Clean Energy Initiative. Retrieved from https://www.nrel.gov/docs/fy10osti/47891.pdf

[614] Granade, H., et al. (2009). Unlocking the Energy Efficiency in the US Economy.

[615] McCabe, M. (2011). High-Performance Buildings—Value, Messaging, Financial and Policy Mechanisms. *Pacific Northwest National Laboratory*. Retrieved from http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20176.pdf

[616] Brisson, A., & Duerr, L. (2014). Impact of Affordable Housing on Families and Communities: A Review of The Evidence. *Enterprise Community Partners*. Retrieved from http://homeforallsmc.com/wp-content/uploads/2017/05/Impact-of-Affordable-Housing-on-Families-and-Communities.pdf

[617] Grant, R. & Brito, A. (2010). Chronic Illness and School Performance. *Children's Health Fund.*

[618] US Environmental Protection Agency. (2012). Weatherization Innovation Pilot Program: Program Overview and Philadelphia Project Highlight (Fact Sheet). *Environmental Protection Agency*. Retrieved from doi:10.2172/1033026

[619] Tonn, B., et al. (2014). Health and Household-Related Benefits Attributable to the Weatherization Assistance Program.

[620] Neuhauser, K. (2013). Evaluation of Two CEDA Weatherization Pilot Implementations of an Exterior Insulation and Over-clad Retrofit Strategy for Residential Masonry Buildings in Chicago. *National Renewable Energy Laboratory (NREL), Golden*. DOE/GO-102013-3904. Retrieved from https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/evaluation_ceda_pilots.pdf

[621] Hollander, A. (2014). Weatherization Innovation Pilot Program (WIPP): Technical Assistance Summary. *National Renewable Energy Laboratory (NREL), Golden*. NREL/TP-7A40-62720., CO., 2014. Retrieved from https://www.nrel.gov/docs/fy14osti/62720.pdf

[622] McCabe, M. (2011). High-Performance Buildings—Value, Messaging, Financial and Policy Mechanisms.

[623] Granade, H., et al. (2009). Unlocking the Energy Efficiency in the US Economy.

[624] *Ibid.*

[625] Robert, S. (1999). Socioeconomic Position and Health: The Independent Contribution of Community Socioeconomic Context. *Annual Review of Sociology, Vol. 25, 489-516*. Retrieved from http://www.annualreviews.org/doi/abs/10.1146/annurev.soc.25.1.489

[626] Drewnowski, A., & Specter, S. (2004). Poverty and Obesity: the Role of Energy Density and Energy Costs. *The American Journal of Clinical Nutrition, Vol. 79(1) 6-16.* Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/14684391

[627] Walker, R., Keense, C., Burke, J. (2010). Disparities and Access to Healthy Food in the United States. A Review of Food Deserts Literature. *Health & Place,Vol. 16 (5) 876-884*. Retrieved from http://www.sciencedirect.com/science/article/pii/S1353829210000584

[628] Bonanno, A. (2012). Food Deserts: Demand, Supply, and Economic Theory. *Choices: the Magazine of Food, Farm, and Resource Issues, Agricultural & Applied Economics Association,27(3)*. Retrieved from http://ageconsearch.umn.edu/bitstream/138940/2/cmsarticle_255.pdf

[629] Balfanz, R., & Byrnes, V. (2012). The Importance of Being in School: A Report on Absenteeism in the Nation's Public Schools. *Johns Hopkins University School of Education*. Retrieved from http://new.every1graduates.org/wp-content/uploads/2012/05/FINALChronicAbsenteeismReport_May16.pdf

[630] Williams, D. (2003). The Health of Men: Structured Inequalities and Opportunities. *The American Journal of Public Health, 93(5), pp. 724-731*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1447828/

[631] Hendricks, B., Goldstein, B., Detchon, R., Shickman, K. (2009). Rebuilding America: A National Policy Framework for Investment in Energy Efficiency Retrofits. *Center for American Progress*. Retrieved from https://www.americanprogress.org/issues/green/reports/2009/08/10/6602/rebuilding-america/

[632] Ibid

[633] US Green Building Council. (2008). Green Jobs Study 2008. *Booz Allen Hamilton*. Retrieved from www.usgbc.org/ShowFileaspx?DocumentID=6435

[634] Ibid

[635] Patterson, E. (1991). Poverty, Income Inequality, and Community Crime Rates. *Criminology, Volume 29(4), 755-776*. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1745-9125.1991.tb01087.x/abstract

[636] Davis, R., Cook, D., Cohen, L. (2005). A Community Resilience Approach to Reducing Ethnic and Racial Disparities in Health. *American Journal of Public Health 95(12): 2168-2173*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1449502/

[637] Wells, M. (2010). Resilience in Older Adults Living in Rural, Suburban, and Urban Areas. *Online Journal of Rural Nursing and Health Care, Vol 10(2.)* Retrieved from http://rnojournal.binghamton.edu/index.php/RNO/article/view/55

[638] Friborg, O., Barlaug, D., Martinussen, M., Rosenvinge, J., Hjemdal, O. (2005). Resilience in Relation to Personality and Intelligence. *International Journal of Methods in Psychiatric Research,14(1),29-42*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16097398

[639] Eachus, E. (2014). Community Resilience: Is it Greater than the Sum of the Parts of Individual Resilience? *Procedia Economics and Finance (2014) Vol. 18, 345-351*. Retrieved from http://www.sciencedirect.com/science/article/pii/S2212567114009496

[640] Davis, R., et al. (2005). A Community Resilience Approach to Reducing Ethnic and Racial Disparities in Health.

[641] Wilson, S. (2009). An Ecologic Framework to Study and Address Environmental Justice and Community Health Issues. *Environmental Justice,2(1): 15-24*. Retrieved from http://online.liebertpub.com/doi/abs/10.1089/env.2008.0515

[642] Lindsay, B., Painter, W., McCarthy, F. (2016). An Examination of Federal Disaster Relief Under the Budget Control Act. *Congressional Research Service*. Retrieved from https://fas.org/sgp/crs/misc/R42352.pdf

[643] National Infrastructure Advisory Council. (2016).Water Sector Resilience: Final Report and Recommendations. Retrieved from https://www.dhs.gov/sites/default/files/publications/niac-water-resilience-final-report-508.pdf

[644] U.S. Government Accountability Office. (2008). Green Affordable Housing: HUD Has Made Progress in Promoting Green Building, but Expanding Efforts Could Help Reduce Energy Costs and Benefit Tenants. *Government Accountably Office*. Retrieved from http://www.gao.gov/assets/290/282596.pdf

[645] Ibid

[646] Tonn, B., & Peretz, J. (2007). State-Level Benefits of Energy Efficiency. *Energy Policy 35, no. 7,3665-3674*. Retrieved from https://www.researchgate.net/publication/222537550_State-level_benefits_of_energy_efficiency

[647] California Energy Commission. (2015). Public Interest Energy Research 2014 Annual Report. Retrieved from http://www.energy.ca.gov/2015publications/CEC-500-2015-009/CEC-500-2015-009-CMF.pdf

[648] Ibid

[649] Tonn, B., & Peretz, J. (2007). State-Level Benefits of Energy Efficiency.

[650] California Energy Commission. (2015). Public Interest Energy Research 2014 Annual Report.

[651] *Ibid*., 66

[652] California Energy Commission. (2015). Integrated Energy Policy Report. Retrieved from http://www.energy.ca.gov/2015_energypolicy/

[653] Jackson, J. (2009). How risky are Sustainable Real Estate Projects? An Evaluation of LEED and ENERGY STAR Development Options. *Journal of Sustainable Real Estate 1, no. 1,91-106*. Retrieved from http://energybudgetsatrisk.com/risks_of_sustainable_real_estate_projects.pdf

[654] Ibid

[655] Jackson, J. (2009). How Risky Are Sustainable Real Estate Projects?

[656] Steinberg, D., & Zinaman, O. (2014). State Energy Efficiency Resource Standards: Design, Status and Impacts. *National Renewable Energy Laboratory (NREL), US Dept. of Energy Technical Report, NREL/TP-6A20-61023*. Retrieved from https://www.nrel.gov/docs/fy14osti/61023.pdf

[657] Tonn, B., & Peretz, J. (2007). State-Level Benefits of Energy Efficiency.

[658] Ibid

[659] Steinberg, D., & Zinaman, O. (2014). State Energy Efficiency Resource Standards: Design, Status and Impacts.

[660] Ibid

[661] Ibid

[662] Clearly, J., & Kopicki, A. (2009). Preparing the Workforce for a 'Green Jobs' Economy. *John J. Heldrich Center for Workforce Development Research Brief*. Retrieved from http://www.mdworkforce.org/board/bdmeet/march112009hgbrief.pdf

[663] Ibid

[664] Ibid

[665] Anderson, D., Belzer, D., Livingston, O., Scott, M. (2014). Assessing National Employment Impacts of Investment in Residential and Commercial Sector Energy Efficiency: Review and Example Analysis. *Pacific Northwest National Laboratory (PNNL), PNNL-23402*. Retrieved from http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23402.pdf

[666] Burton, M. (2014). Macro-Economic Impacts of the Weatherization Assistance Program for Program Year 2008. *Oak Ridge National Laboratory*. ORNL/TM-2014/9. Retrieved from http://weatherization.ornl.gov/Retrospectivepdfs/ORNL_TM-2014_98.pdf

[667] Tonn, B., et al. (2015). Weatherization Works II.

[668] McNeil, M.A., Bodja, N., Ke, J., Qin, Y., …& McMahon, J.E. (2011). Business Case for Energy Efficiency in Support of Climate Change Mitigation, Economic and Societal Benefits in China. *Ernest Orlando Lawrence Berkeley National Laboratory*. Retrieved from https://eta.lbl.gov/publications/business-case-energy-efficiency

[669] Ibid

[670] Burton, M. (2014). Macro-Economic Impacts of the Weatherization Assistance Program for Program Year 2008.

[671] Tonn, B., et al. (2015). Weatherization Works II.

[672] US Green Building Council. (2008). Green Jobs Study 2008.

[673] Ibid

[674] Ibid

[675] Steinberg, D., & Zinaman, O. (2014). State Energy Efficiency Resource Standards: Design, Status and Impacts. *National Renewable Energy Laboratory (NREL), US Dept. of Energy Technical Report, NREL/TP-6A20-61023*. Retrieved from https://www.nrel.gov/docs/fy14osti/61023.pdf

[676] American Council for an Energy Efficient Economy. (2017). State Energy Efficiency Resource Standards Policy Brief. Retrieved from http://aceee.org/sites/default/files/state-eers-0117.pdf

[677] Kushler, M., Nowak, S., Witte, P. (2012). A National Survey of State Policies and Practices for the Evaluation of Ratepayer-Funded Energy Efficiency Programs. *American Council for an Energy-Efficient Economy*. Retrieved from https://aceee.org/research-report/u122

[678] California Public Utilities Commission. (2001). California Standard Practice Manual. Retrieved from http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/

[679] Kushler, M., et al. (2012). A National Survey of State Policies and Practices for the Evaluation of Ratepayer-Funded Energy Efficiency Programs.

[680] Skumatz, L., Khawaja, M., Colby, J. (2009). Lessons Learned and Next Steps in Energy Efficiency Measurement and Attribution: Energy Savings, Net to Gross, Non-Energy Benefits, and Persistence of Energy Efficiency Behavior. *Skumatz Economic Research Associates for California Institute for Energy and Environment*. Retrieved from https://uc-ciee.org/downloads/EEM_A.pdf

[681] Kushler, M., et al. (2012). A National Survey of State Policies and Practices for the Evaluation of Ratepayer-Funded Energy Efficiency Programs.

[682] Ibid

[683] Skumatz, L., Khawaja, M.S., & Krop, R. (2010). Non-Energy Benefits: Status, Findings, Next Steps, and Implications for Low Income Program Analyses in California: REVISED REPORT. *Skumatz Economic Research Associates*. Retrieved from http://energyefficiencyforall.org/resources/non-energy-benefits-status-findings-next-steps-and-implications-low-income-program

[684] Woolf, T., Steinhurst, W., Malone, E., Takahashi, K. (2012). Energy Efficiency Cost-Effectiveness Screening. *Synapse Energy Economics, Inc*. Retrieved from http://www.synapse-energy.com/sites/default/files/SynapseReport.2012-11.RAP_.EE-Cost-Effectiveness-Screening.12-014.pdf

[685] Skumatz, L. et al. (2010). Non-Energy Benefits: Status, Findings, Next Steps, and Implications for Low Income Program Analyses in California.

[686] Woolf, T., et al. (2012). Energy Efficiency Cost-Effectiveness Screening.

[687] Ibid

[688] Vermont Public Service Board. (2012). Order Re: Cost-Effectiveness Screening of Heating and Process Fuel Efficiency Measures and Modifications to State Cost Effectiveness Screening Tool. Retrieved from http://psb.vermont.gov/sites/psb/files/orders/2012/2012-4/OrderReCostEffectivenessScreeningofHeating.pdf

[689] Skumatz, L. (2014). Non-Energy Benefits / Non-Energy Impacts (NEBs/NEIs) and their Role & Values in Cost-Effectiveness Tests: State of Maryland. *Skumatz Economic Research Associates*. Retrieved from http://energyefficiencyforall.org/sites/default/files/2014_%20NEBs%20report%20for%20Maryland.pdf

[690] Coalition of Maryland Energy Efficiency Advocates. (2015). Comment on Case Nos. 9153, 9154,9156,9157. Retrieved from http://www.psc.state.md.us/wp-content/uploads/Order-No.-87082-Case-Nos.-9153-9157-9362-EmPOWER-MD-Energy-Efficiency-Goal-Allocating-and-Cost-Effectiveness.pdf

[691] Maryland Public Service Commission. (2015). Order 87082. *Retrieved from http://www.psc.state.md.us/order-no-87082-case-nos-9153-9157-9362-empower-md-energy-efficiency-goal-allocating-and-cost-effectiveness/*

[692] US Environmental Protection Agency. (2015). Overview Of The Clean Power Plan: Cutting Carbon Pollution From Power Plants. Retrieved form http://www.epa.gov/airquality/cpp/fs-cpp-overview.pdf

[693] Ibid

[694] US Department Of Energy. (2011). Weatherization Program Notice, 11-6.

[695] Hernández, D., & Bird, S. (2010). Energy Burden and the Need for Integrated Low-Income Housing and Energy Policy. *Poverty & Public Policy, 2(4), 5-25*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/27053989

[696] Tonn, B., et al. (2015). Weatherization Works II.

[697] Malmgren, I., & Skumatz, L. (2014). Lessons from the Field: Practical Application for Incorporating Non-Energy Benefits into Cost-Effectiveness Screening. *American Council for an Energy Efficient Economy*. Retrieved from http://aceee.org/files/proceedings/2014/data/papers/8-357.pdf

[698] Berwick, D., Nolan, T., Whittington, J. (2008). The Triple Aim: Care, Health, and Cost. *Health Affairs, 27(3), 759-769*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18474969

[699] Nelson, G., Mueller, C., Wells, T., Boddie-Willis, C., Woodcock, C. (2015). Hospital Community Benefits After the ACA: State Law Changes and Promotion of Community Health. *The Hilltop Institute*. Retrieved from https://www.rwjf.org/en/library/research/2015/02/hospital-community-benefits-after-the-aca.html

[700] Bensch, I., Keene, A., Cowan, C., Koski, K. (2014). National Weatherization Assistance Program Characterization: Describing the Pre-ARRA Program. *Oak Ridge National Laboratory. ORNL/TM-2013/188*. Retrieved from http://info.ornl.gov/sites/publications/files/Pub42684.pdf

[701] U.S. National Library of Medicine. (2015). Medical Subject Headings Fact Sheet. Retrieved from https://www.nlm.nih.gov/pubs/factsheets/mesh.html

[702] National Heart, Lung, and Blood Institute. (2017). National Asthma Education and Prevention Program. Retrieved from https://www.nhlbi.nih.gov/about/org/naepp

PHOTOS

P. 1 (right), 59, courtesy of 242 Creative
P. 16, 110: courtesy of Elevate Energy
P. 21, 101: courtesy of Wishrock Group

ACKNOWLEDGEMENTS

The Green & Healthy Homes Initiative would like to thank the JPB Foundation and the Energy Foundation for their generous support for this publication.

Energy Foundation
The JPB Foundation

Green & Healthy Homes Initiative®
2714 Hudson Street
Baltimore, Maryland 21224-4716
Main: 410-534-6447
1-800-370-5323
greenandhealthyhomes.org | twitter.com/healthyhousing | facebook.com/GHHInational/
linkedin.com/company/green-and-healthy-homes-initiative