Occupant Health Benefits of Residential Energy Efficiency

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Foreword

Steve Cowell, E4TheFuture

Energy efficiency (EE) creates many sources of value beyond just reducing energy costs. Recognition and acknowledgement of these multiple benefits is on the rise. Energy efficiency enhances system sustainability and builds energy security, supports economic development by creating new jobs, reduces disproportionate energy burdens borne by low-income customers, and improves public health by reducing outdoor air pollution caused by power plant emissions.

More recently, there is increased interest in understanding the potential home occupant health benefits of EE investments due to improved indoor air quality, safety, and comfort. EE providers are exploring ways to work with health partners to leverage the EE workforce. While delivering EE, workers can identify opportunities that may improve health outcomes, particularly for occupants with pre-existing health risks linked to their home environment.

To help inform and prompt discussion across a range of audiences on these health co-benefits from residential EE investments, E4TheFuture engaged a team of experts. Our goal was to review existing research on residential EE measures and associated health impacts, discuss ways that programs monetize occupant health co-benefits, highlight innovative programs that combine EE and health-focused home repairs, and identify research gaps and strategies to help advance and leverage funding across such integrated efforts.

E4TheFuture is pleased to present this paper, with its key findings and recommendations. We encourage residential EE program administrators, implementers, regulators, funders, and advocates to build their knowledge and understanding of the potential occupant health benefits of EE activities, as well as the methodologies to fully value health co-benefits in EE program cost-effectiveness practices[1].

[1] A forthcoming publication of a National Standard Practice Manual for Cost-Effectiveness Screening (2017), being developed by the Home Performance Coalition, will provide additional principles and guidance on identifying and quantifying non-energy benefits.

Project Team

About Tohn Environmental Strategies (TES)

Tohn Environmental Strategies is an environmental and health policy consulting firm with over 25 years of experience in environmental health, healthy housing, green building, indoor air quality and lead poisoning prevention. TES has advised Federal and state agencies and non-profit organizations in designing healthy housing and indoor air quality elements for green building and energy retrofit programs; developed green and healthy housing programs; conducted environmental health research studies; provided strategic planning at the intersection of health, housing and energy efficiency; and worked with property owners, developers and managers to design, construct and manage green and healthy housing.

About The National Center for Healthy Housing (NCHH)

NCHH, a nonprofit corporation, is dedicated to developing and promoting practical, validated, and effective methods to address residential environmental health hazards. Founded as the National Center for Lead-Safe Housing in 1992, NCHH is the nation's principal proponent of evidence-based policies and techniques for identifying and reducing health hazards in our nation's housing stock. Since its inception, NCHH has managed over 100 multi-disciplinary projects totaling over $20 million. NCHH's staff includes housing, health, and environmental experts in biostatistics, environmental health, public health, housing policy, toxicology, and industrial hygiene. It has worked with a broad array of stakeholders including federal, state, and local agencies, universities, and private research institutions and has published and contributed to over fifty articles and reports on environmental health and housing issues.

About Three^3

The mission of Three^3 is to foster equitable, sustainable futures. It is widely accepted that the three components, or pillars of sustainability, are environment, equity, and economics, in combination. Three^3 conducts innovative, interdisciplinary research and offers educational programming to promote the integrated achievement of sustainability goals in these areas. We provide research and evaluation services, with particular expertise in energy efficiency; program evaluation and sustainability planning support; and facilitation services to support sustainable development.

About E4TheFuture (E4)

E4TheFuture is a nonprofit organization working to advance safe, efficient energy solutions with a focus on residential customers. "E4" encompasses: promoting clean, efficient **Energy;** growing a low-carbon **Economy;** ensuring **Equity** by providing *all* Americans with clean, efficient, affordable energy; and restoring a healthy **Environment** for people, prosperity and the planet. Our endowment and primary leadership comes from Conservation Services Group (CSG), which provided low-cost clean energy solutions 1984-2015 in over half of U.S. states helping to improve more than 3.8 million homes.

Acknowledgements: *We would like to thank Gary Adamkiewicz, Harvard School of Public Health and Kevin Kennedy, Children's Mercy Hospitals and Clinics for their review and comments in the preparation of this document.*

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Common Acronyms

ASHRAE: American Society of Heating Refrigeration and Air Conditioning Engineers

CO: Carbon Monoxide

CO_2: Carbon Dioxide

COPD: Chronic Obstructive Pulmonary Disease

ED: Emergency Department

ERV: Energy Recovery Ventilator

HRV: Heat Recovery Ventilator

HVAC: Heating, Ventilation, and Air Conditioning

NO_2: Nitrogen Dioxide

NEBs: Non Energy Benefits

NEIs: Non Energy Impacts

OR: Odd Ratio

pCi/L: Picocuries per Liter

RH: Relative Humidity

WAP: Weatherization Assistance Program

Executive Summary

Residential energy efficiency (EE) program administrators and other stakeholders are increasingly interested in understanding the potential occupant health benefits of EE upgrades in homes, and the methodologies to fully value health co-benefits in EE program cost-effectiveness practices. Interest is growing in exploring opportunities to work with health partners to leverage the EE workforce to improve health outcomes, particularly for those with pre-existing health risks linked to their home environment.

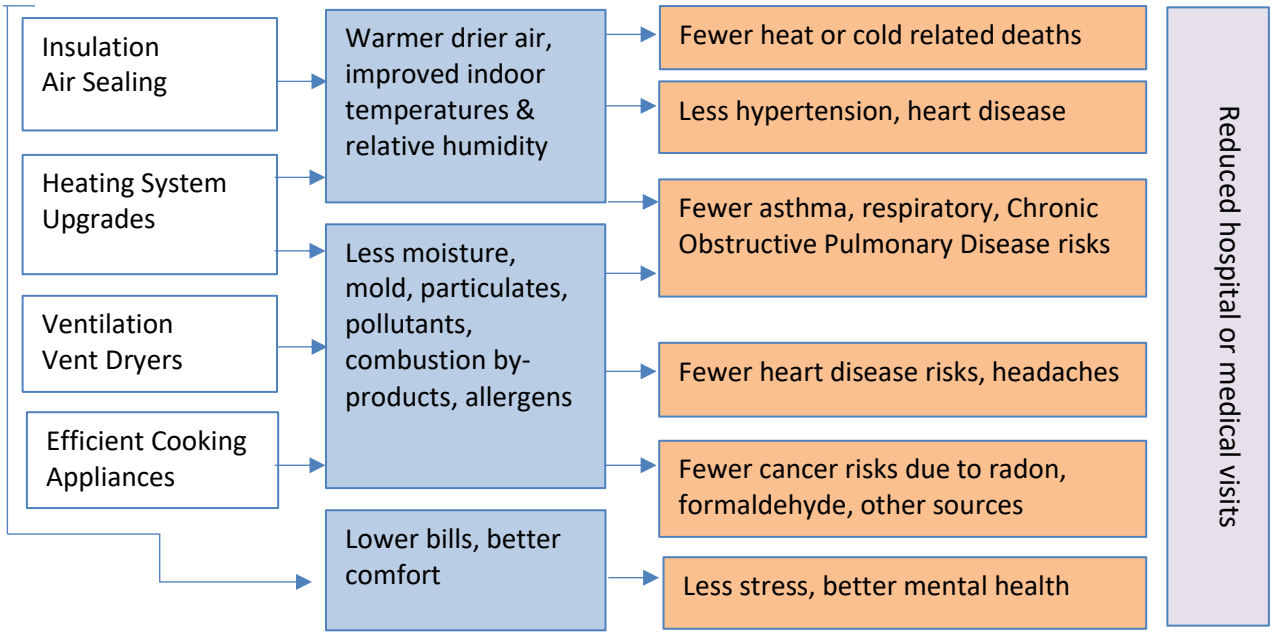
To help inform and prompt discussion across a range of audiences on the health co-benefits from residential EE investments, this paper reviews research studies of residential EE and related ventilation upgrades, discusses ways that programs have monetized occupant health co-benefits, and highlights innovative programs that combine EE and health-focused home repairs. The paper concludes with identifying research gaps and strategies to help advance such work.

This paper focuses on research studies conducted in the United States (US) and Canada. It includes one international study due to its robust findings. Importantly, this paper builds upon a broader literature review conducted by the US Department of Energy (DOE), *Home R_x: The Health Benefits of Home Performance: A Review of Current Evidence,* which was developed to summarize studies that evaluated occupant health related outcomes associated with energy upgrades and home performance improvements. The DOE report considers both US and international studies.

Potential Occupant Health Impacts From Residential EE

Residential EE programs typically improve the building envelope and heating systems, creating warmer and more comfortable homes. The pathways by which home energy upgrades can also help to improve indoor environmental conditions and occupant health is shown in Figure ES1.

Figure ES1: Occupant Health and Indoor Environmental Benefits of Residential EE



What the EE Studies Tell Us

Twelve studies of residential EE and two studies of related ventilation strategies all document some improvement in occupant health or indoor environmental conditions. Some studies also observed reductions in asthma or respiratory related emergency department (ED) or hospital visits. Results of the EE studies are summarized in Table ES1 below.

Table ES1: Occupant Health Benefits of Residential EE

Reduced Respiratory & Allergy Symptoms	Other Health Improvements	Reduced Emergency Dept. Visits or Hospitalizations	Indoor Environmental Conditions
Allergies	Headaches	Asthma	Moisture
*Asthma**	Hypertension	Other respiratory	Condensation
Colds	Thermal stress		VOCs
Sinusitis	Overall health		*Formaldehyde*
Throat irritation	Mental health		*Radon*
Wheeze			

Italics: some negative outcomes VOCs: Volatile Organic Compounds

* The majority of studies reported asthma improvements; one study documented mixed results

Improvements in asthma symptoms and related health care use are significant because asthma affects roughly 1 in every 14 adults (7%) and a greater percentage of lower income adults (16% of adults in households receiving Department of Energy (DOE) funded weatherization). (CDC 2016; Tonn et al. 2014) Experts estimate that 40% of diagnosed asthma is associated with home exposures (e.g., moisture, temperature variations, pests), some of which can be improved through EE and related ventilation. (RWJ 2009)

Key study findings are presented below; examples of research findings described in the full report are also highlighted.

12% fewer asthma ED visits and 48% decline in poor health among adults in households receiving DOE funded weatherization
Tonn et al. 2014

23% reduction in poorly controlled asthma for children in homes receiving EE, some home repairs & education compared to those receiving only education
Breysse et al. 2014

- **Occupants can experience fewer asthma symptoms and respiratory related ED visits after EE.**
- **Occupants report better physical and mental health after EE.**
- **Programs delivering EE with added home repairs and client education can produce more significant improvements in asthma symptoms and indoor environmental conditions.**
- **Improvements in occupant health are strongest among vulnerable groups: lower income households and residents with pre-existing health conditions linked to housing risks.**
- **Whole house ventilation strategies using heat or energy recovery ventilators (HRVs or ERVs) can reduce asthma and respiratory symptoms in children with pre-existing risks. Such strategies are increasingly being considered in EE programs.**
- **Homes receiving EE can experience increases in radon or formaldehyde; ventilation systems may offer the potential to reduce radon in such homes.**

- **The majority of studies were conducted in single family lower income homes located in predominately northern heating climates.**

Given this evidence, it is not appropriate to value the health co-benefits of low income residential energy retrofits at $0 in program design or cost-effectiveness practices.

Innovative Energy and Health Programs Are Testing New Models

EE programs are testing innovative approaches and developing new partnerships to improve occupant health. Some programs offer integrated energy and health home upgrades. Others are linking EE programs with health referrals and building strong local collaborations. Often these programs are targeting clients with pre-existing respiratory or other housing-based health risks. Of importance is the relatively new Building Performance Institute (BPI) Healthy Homes Evaluator Credential, which provides added health training to the EE workforce. This certification program can help to support these new innovative programs.

A Road Map for Action

Studies show that residential EE programs can help to improve occupant health. To help promote EE programs that improve health and engage health partners, we should pursue four key activities. These are described in more detail beginning on page 28.

1. Share Results	• Widely distribute occupant health research to energy and health partners • Engage energy regulators to incorporate occupant health co-benefits into program design and cost-effectiveness practices
2. Support Innovative Programs	• Support EE programs addressing occupant health and engaging health partners • Promote funding models, work practices, evaluation, and health collaborations
3. Fill Research Gaps	• Assess EE and health focused home repairs for clients with respiratory risks • Evaluate practices to minimize radon and formaldehyde risks • Examine EE in warm climates, market rate, and multifamily homes • Pursue studies with comparison groups to provide robust results
4. Define & Share Best Practices	• Promote EPA Guidance on health benefits during energy upgrades • Update guidance and tools to reflect current research and best practices

I. Introduction

Residential energy efficiency (EE) upgrades to building envelopes and heating systems can improve indoor environmental conditions and create healthier living conditions. This has been demonstrated in particular in low income weatherization programs. Occupant health benefits are of increasing interest to those designing, funding, and delivering energy programs in both low income and non-low income homes, as well as to healthcare system partners.

This report addresses key questions being asked by EE program administrators and other stakeholders:

1. To what extent do EE programs and practices help to improve the health of occupants by reducing asthma risks, respiratory symptoms, and other health risks linked to home conditions?
2. Have we fully or appropriately valued the occupant health co-benefits of EE programs in program cost-effectiveness screening practices?
3. How might EE programs be modified to better identify occupants with health risks and create greater health benefits, in both low income and non-low income homes? How can the EE industry work with healthcare system partners to leverage the EE workforce to improve health outcomes?
4. What additional research is needed to better understand the health impacts of EE programs?

This report addresses these questions by reviewing health impact research of residential EE programs and related ventilation improvements (Section II & III), discussing ways programs have monetized occupant health co-benefits (Section IV), and providing examples of innovative programs that combine home EE upgrades with health focused home repairs or occupant education (Section V). Finally, we offer recommendations in a Roadmap for Action (Section VI) to widely share what is known about health benefits of EE, support innovative collaborative program models and best practices, and address research gaps.

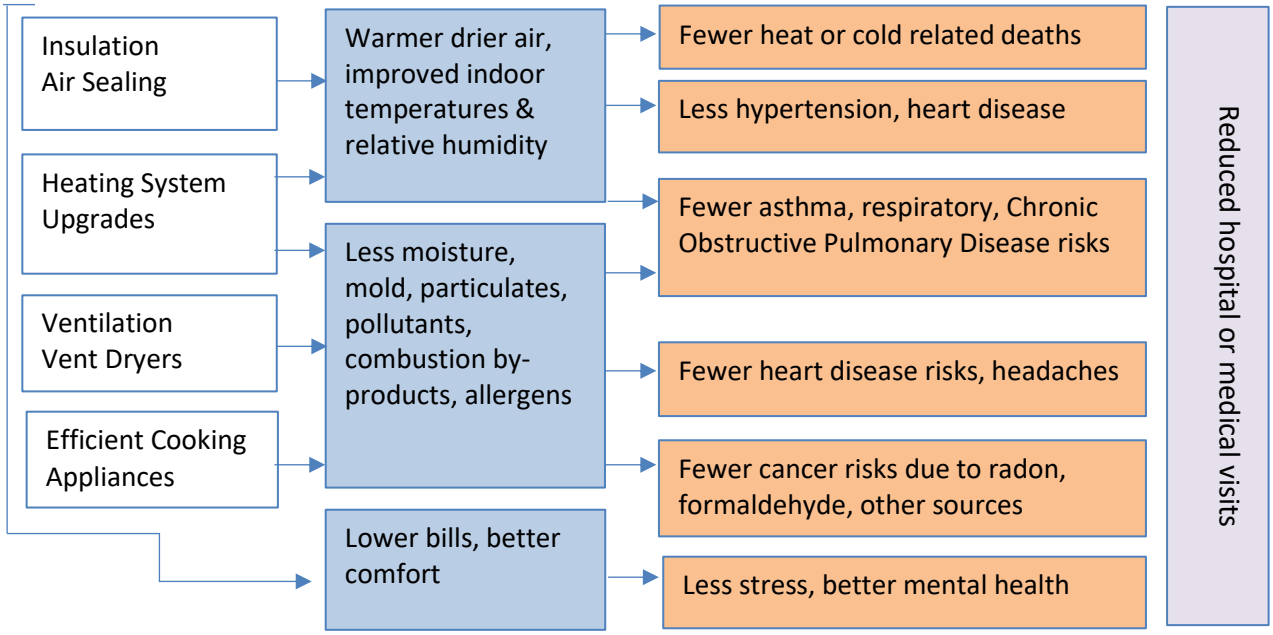
The research review focuses on studies conducted in the United States (US) and Canada, given the consistency of the housing stock. One international study is referenced because it provides particularly robust findings. Information about innovative EE programs that are integrating health priorities or partners was gathered from websites, webinars, and interviews.

Importantly, the report builds upon a broader literature review conducted by the U.S. Department of Energy (DOE) and international studies relevant to the EE and home performance industries. DOE's report, entitled *Home R_x: The Health Benefits of Home Performance: A Review of Current Evidence,* summarizes a wide range of studies and identifies research gaps related to: EE, ventilation, green renovation and construction, and supplemental home services that home performance contractors might undertake to create healthier living environments.

II. Potential Occupant Health and Indoor Environmental Improvements

While most residential EE work is not focused on improving occupant health, common EE activities can create a drier home with more consistent temperatures, fewer air indoor pollutants, reduced allergens, and fewer asthma triggers (changes in temperatures, dampness, mold, mice or cockroach droppings). Such changes have the potential to reduce resident health risks as depicted in Figure 1 and discussed below. In general, most research studies assess the health impact of a bundled set of EE services and not specific EE actions.

Figure 1: Occupant Health and Indoor Environmental Benefits of Residential EE



- **Asthma and Other Respiratory Symptoms** Approximately 7% of the US population is affected by asthma; 16% of adults in the Weatherization Program National Evaluation reported having asthma. (Tonn et al. 2014; CDC 2016) Living in a home with moisture/dampness, mold, pests (cockroaches or mice), cold or inconsistent temperatures, environmental tobacco smoke, dust mites, or indoor air pollutants can increase the risks of asthma attacks, wheezing, and other respiratory symptoms. (RWJ 2009; Fisk et al. 2007). Air sealing and insulation can improve indoor temperatures, reduce dampness or moisture issues, and exclude mice and cockroaches. Repairs or upgrades to HVAC system, as well as new tight windows and doors, can help reduce air pollutants.
- **Chronic Obstructive Pulmonary Disease (COPD) Symptoms in Adults** COPD refers to a group of diseases that cause airflow blockage and breathing-related problems, including emphysema and chronic bronchitis. According to the Centers for Disease Control (CDC), approximately 15 million adults report COPD (6% of adults) and it is the third leading cause of death among US adults. (CDC 2016) Improving indoor temperatures to create warmer homes, and reducing fine particulate matter and air pollutants through improved

ventilation and heating system/cooking appliance upgrades, can help to reduce potential COPD risks.

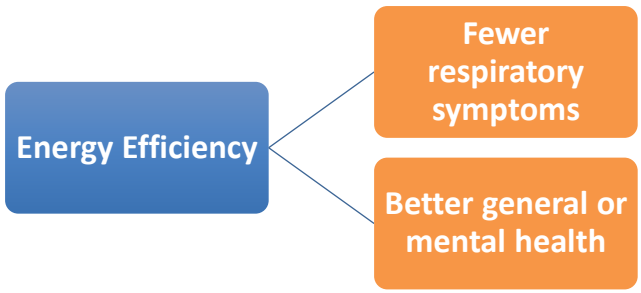
- **Allergy and Sinus Infection Risks** Allergies may affect up to 30% of adults and 40% of children; 12% of adults have sinusitis (sinus infections). (AAFA 2016; CDC 2016) EE that addresses home moisture, mold, cold temperatures, and pests through air sealing and insulation, can reduce some allergens and potential risks for sinus infections. Controlling the infiltration of outdoor air through air sealing, improved air filtration, installation of new doors and windows, and upgraded HVAC systems, can also help to reduce exposure to outdoor allergens.
- **Cancer Risks** The Environmental Protection Agency (EPA) estimates that 21,000 lung cancer cases per year are associated with radon exposure. (EPA 2003) Radon exposures can be minimized through ventilation and air sealing. Formaldehyde exposures, also linked to cancer, may be reduced through enhanced ventilation.
- **Hypertension and Cardiovascular Risks** Approximately 30% of Americans struggle with hypertension, a risk factor for cardiovascular risks. (CDC 2015) Improvements in indoor temperatures and reduction of particulates from outdoor air (by filtration of outdoor air in heating systems and/or air sealing) can help to reduce conditions that can exacerbate hypertension.
- **Headaches** EE activities can reduce moisture through air sealing and insulation, reduce exposure to indoor air contaminants through heating system/cooking appliance upgrades and ventilation, and stabilize indoor temperatures. Such improvements may help to reduce headache risks in some individuals.
- **Death or Injuries Due to Extreme Heat or Cold, Carbon Monoxide Poisoning, Or Fires** Exposure to extreme heat, cold, carbon monoxide (CO) or fires can result in death. CO exposures can also create headaches, dizziness, weakness, upset stomach, vomiting, chest pain, confusion, or “flu-like” symptoms. Many EE programs test and address harmful CO emissions from combustion appliances and install CO alarms to prevent future exposures. Fire risks can be reduced by addressing electrical wiring risks and faulty combustion appliances. Installation of smoke detectors can help prevent fire-related injuries or death.
- **Overall Physical Health** General physical health is impacted by exposures to extreme cold or heat, dampness, indoor air contaminants, and stress which can exacerbate other poor health outcomes. EE interventions can improve these home environmental conditions and reduce financial hardships that can increase stress (difficulty paying energy bills in lower income families) by lowering household fuel bills.
- **Mental Health** Mental health can be impacted by both physical environmental conditions and financial hardships due to fuel bills. EE can help make homes warmer or reduce temperatures in homes prone to overheating, reduce high energy bills which can create stress, and improve environmental conditions that can disrupt sleep (dampness, cold, air contaminants).

III. What the Studies Tell Us

We reviewed a total of 14 studies that examined the occupant health or indoor environmental benefits of residential EE and/or ventilation upgrades. A range of core EE measures were undertaken, which included: insulation, air sealing, and heating system repairs/upgrades. Enhanced ventilation, additional housing repairs, and/or occupant education were added to core EE in several studies. One study examined window replacements. Ventilation-only retrofits were also evaluated to provide insights on this specific measure, which is being considered in EE programs that are increasing building tightness and exploring mechanical ventilation strategies.

The studies tracked several outcome metrics: 1) the health of those living in the homes (i.e., occupant health), 2) occupant health care utilization or health care costs, and 3) indoor environmental conditions. The collective impact of these three health related metrics is summarized into two broad categories: fewer respiratory symptoms or improvements in general physical or mental health (Figure 2). We describe the study results using these two categories. The report also summarizes the benefits of stand-alone ventilation studies in a separate subsection.

Figure 2: Occupant Health Improvements From EE



Interpreting Health Study Results

The majority of studies focused on occupant health as the key outcome metric. Occupant health was typically measured based on **occupant self-reports** using validated health questionnaires. Validated questionnaires have been tested to demonstrate that interviewees will provide similar responses when their health conditions are similar. Occupant self-reported health has been shown to be a good predictor of clinical health. In a few cases, researchers tracked empirical health measures (e.g., lung function, blood pressure). Most studies looked at health effects over a one- to two-year window after the EE measures were installed.

A few studies tracked the impact of the EE on **health care utilization** or **health care costs.** Health care utilization was tracked through occupant surveys or a review of health care claims (e.g., Medicaid). Health care costs were measured through reviews of health records (e.g., Medicaid costs) or through monetization of occupant reported health care use. Several studies measured **indoor environmental conditions**, which were tracked through occupant self-reports; on-site observations from trained staff; or environmental sampling (air sampling, dust allergens, and/or data loggers).

In terms of the level of certainty in the study results and strength of the study design, we note three factors: a) the extent to which comparison groups were used, b) the targeting of individuals with pre-existing health risks, and c) the statistical significance of the results, which provides a way to assess our confidence in the observed outcome. In general, studies with a control or comparison group can produce more robust results because they can demonstrate that changes are related to EE and not to other factors influencing occupant health or environmental conditions in similar households. Studies that enroll individuals with pre-existing health conditions (versus studies that enroll homes needing EE with no knowledge of occupant health risks) have a greater likelihood of documenting health improvements and reductions in health care use because they focus on a population at greater risk. The criteria used to report statistical results are discussed below.

The report describes results where there is a high degree of confidence that the changes observed were due to the EE or ventilation work. We present results that have a statistical significance at a value generally accepted by the health research community ($p<0.05$). Such results indicate a 95% confidence level that there was an actual difference in outcomes between the two groups (e.g., occupant self-reports before and after the EE projects), the difference was not due to chance (+/- 5%), and thus we can be highly confident of the change. In a few instances, we include study results that reached a 90% confidence that there was an actual difference in outcomes ($p<.10$), which is still considered a positive result.

In addition to p-values, some researchers used another approach to describe a change in outcomes: an odds ratio (OR). We include ORs when the results indicate a change in outcomes that is not likely due to chance. When odds ratios are presented and the value is less than 1, EE is associated with lower odds of the outcome than if EE had not occurred. For example, if the OR is .5 for occupant ED visits due to asthma in the homes receiving an energy upgrade versus similar homes that did not receive the EE, we can say that the resident is half as likely to have an ED visit after weatherization work than if no work was done. If the OR was greater than 1 for this same work, we would conclude that homes that received EE are more likely to result in occupant ED visits due to asthma than in homes that did not receive EE.

Summary of EE and Ventilation Projects Evaluated

The report reviewed 14 studies. 12 studies evaluated EE and two studies examined stand-alone ventilation work. Table 1 summarizes the types of work conducted and notes studies that targeted individuals with pre-existing respiratory risks and used a comparison group (***green italics***). Table 2 provides more detailed information about the study design and program activities.

- Nearly all studies involved some insulation work. All the North American studies included some air sealing and heating system repairs or upgrades (excluding one study of only window replacement).
- Five studies included more extensive EE activities (e.g., window replacements), enhanced ventilation, or added home repairs.
- Most studies were conducted on single family low income homes.

- Most studies were performed in a predominately northern heating climate and thus did not include upgrades to cooling systems.
- Five studies targeted individuals with pre-existing respiratory risks and included a comparison group. However, only two of these studies were conducted in the US (Breysse & Rose).
- Two studies evaluated whole house ventilation as a stand-alone measure. Ventilation systems are increasingly being considered or installed as part of EE programs.

Table 1: Health Impact Studies by Program Activity

EH: Insulation, air sealing, heating system upgrades	EH with enhanced ventilation	EH and some ventilation, home repairs, education	Window replacement only	Enhanced ventilation only (HRV/ERVs)
Tonn Pigg (2 studies) Wilson Francisco ***Rose**** ***Howden-Chapman***	Leech Norris	***Breysse*** ***Rose**** Norton	Jacobs	***Kovesi*** ***Lajoie***

Notes:

Green italics: Studies targeting individuals with pre-existing respiratory risks with comparison groups

EH: Envelope and heating HRVs: Heat Recovery Ventilators ERVs: Energy Recovery Ventilators

*Rose et al. 2015 tracked health care use and costs in three groups: weatherization; weatherization plus added health repairs; healthy homes interventions with no weatherization.

Table 2: Residential EE Health Impact Studies: Study Design and Program Activity

Study, Lead Author, Publication Date Country, family income, single/multi family	Study Size Comparison Group (y/n)	Program Activity				
		Insulation & air sealing	Heating Repair/ Replacement	Window/Door Replacement	Ventilation	Other
US Weatherization Assistance Program, Tonn et al. 2014 US; low income; single family, mobile	655 homes 882 people; 99 pre/post asthma Y				Exhaust*	Smoke/CO alarms
US Weatherization Assistance Program, Pigg et al 2014 US; low income, single family, mobile	514 homes Y		*		Exhaust*	Smoke/CO alarms
Watts-to-Wellbeing Study, Wilson et al. 2014 US; low income; single & multi family	248 homes N			*	Exhaust*	Smoke/CO alarms
HEALTH-V, Francisco et al. 2016 US, low income, single family	81 homes 171 people Y				Exhaust ASHRAE 62.2	Smoke/CO alarms
US Weatherization Assistance Program, Pigg 2014 US; low income, single family	18 homes N				Exhaust ASHRAE 62.2	Smoke/CO alarms
Highline Communities Healthy Homes Project *Breysse* et al. 2014 US; low income; single family	102 homes Y	*		*	Exhaust*	Remove carpets, CO/smoke alarms, water leak repair
Evaluation of Canadian R-2000 Standard *L*eech et al. 2004 CA; market rate; single family – new construction	105 homes 128 people Y		Energy efficient systems	Energy efficient	Whole-House (HRV)	Healthy material standards, CO alarms
Impact of Weatherization and Healthy Homes Interventions on Asthma-Related Medicaid Claims, Rose 2015 US; low income; single family	49 homes Y			*	Exhaust*	Remove carpet, pest exclusion, mattress cover, dehumidifier, HEPA vacuum
Indoor Environmental Quality Benefits of Apartment Energy Retrofits, Noris et al. 2013 US; market rate; multi family	16 homes N	*	*	*	Whole-House (ERV) Exhaust*	Fan, CO alarms, room HEPA filter*, mold removal*
Replacing Windows Reduces Childhood Lead Exposures: Results From a State Funded Program, Jacobs et al. 2016 US; low income; single & multi family	96 homes N			Energy efficient		
Green and Healthy Homes Initiative: Improving Health, Economic and Social Outcomes Through Integrated Housing Intervention, Norton et al. 2014 US; low income	201 people N					Energy, housing repairs, client education (energy details not specified)
Insulation and Health, Howden-Chapman 2007 NZ; low income; single family	1,128 homes; 3,312 people Y					

*Installed in some dwellings. CA: Canada; US: United States; NZ: New Zealand; CO: Carbon monoxide

Respiratory Related Benefits from EE

Existing studies provide strong evidence that EE has the potential to reduce respiratory symptoms, such as asthma. Nine studies reported changes in respiratory or related symptoms; health care use or costs; or environmental conditions linked to respiratory issues. The key findings are summarized below; a more detailed listing of all respiratory related study results is presented in Table 3.

1. **Studies tracking asthma showed some improvement in symptoms, hospital use, or medication use after EE.** Although the metrics used to measure asthma risks differed, three US studies of low income homes where EE was conducted showed:
   - 12% reduction in asthma-related ED use;
   - a predicted six-fold reduction in the likelihood of visiting an ED after weatherization due to asthma symptoms, based on regression modeling;
   - greater than $400 decline in annual Medicaid costs and fewer Medicaid claims (for homes receiving EE, EE plus health repairs, or healthy homes repairs); and
   - a trend toward a 20% reduction in use of asthma "rescue" medicines. (Tonn et al. 2014; Rose et al. 2015; Wilson et al. 2014)

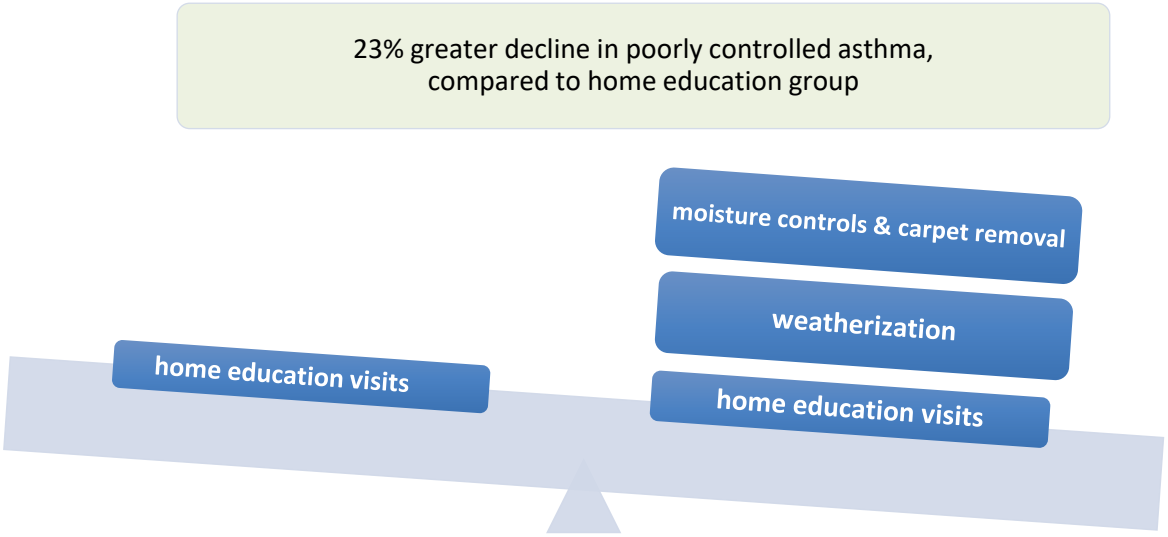
   However, the study that reported a decline in asthma rescue medication use also observed a 26% increase in asthma symptoms. (Wilson et al. 2014)

   A large New Zealand study with a robust control group (over 1,000 people and 3,000 homes) targeting low income individuals with a history of respiratory risks demonstrated over a 50% reduction in the odds of being admitted to the hospital due to respiratory issues, when compared to similar individuals living in homes that did not receive the EE. (Howden-Chapman et al. 2007)

2. **Fewer sinus infections, colds, and allergies were observed after EE.** Improvements included: 9% fewer persistent colds, 5% fewer sinus infections, and 13% less eczema and allergies. (Tonn et al. 2014; Wilson et al. 2014; Francisco et al. 2016)

3. **Greater improvements in asthma symptoms were observed in homes when EE was supplemented with home repairs designed to address home asthma risks.**
   - Parents of children with asthma reported that EE and home repairs supplemented with home asthma education was associated with a 71% improvement in poorly controlled asthma, and a 23% net improvement when compared to a similar group that received only home asthma education (Figure 3). Home education included coaching on compliance with medication instructions. (Breysse et al. 2014)

Figure 3: Asthma Improvements Following EE Plus Health



- Another study of children with asthma who received client education with integrated home and housing repairs documented significant declines in mean number of hospitalizations (65%) and ED visits (28%). However, the extent of the EE performed in the homes studied is not fully described. (Norton et al. 2014)

4. **Improvements in respiratory health are strongest among vulnerable groups: lower income households and residents with pre-existing health conditions linked to housing risks (asthma or other respiratory risks).** Positive health outcomes were observed in programs that targeted lower income households or households where at least one occupant was at risk for asthma or other respiratory risks. (Rose et al. 2015; Tonn et al. 2014; Wilson et al. 2014; Howden-Chapman et al. 2007; Breysse et al. 2014)

Table 3: Respiratory Related Benefits From EE

Author, Date Comparison group	Health Related Outcomes (Statistically significant at p<.05 unless noted)		
	Health Care Use	Asthma or Respiratory Symptoms	Indoor Environmental Conditions
Tonn 2014 EE (Health care and symptom results for treatment group only)	**Asthma ED visits:** 12% reduction; predicted 6 times less likely to visit ED after EE **Ability to pay for prescription drugs or medical care:** improved	**Persistent colds**: 9% less	**Moisture/mold and pests** reduced
Wilson 2014 EE		**Asthma rescue medication**: 20% less * **Sinusitis**: 5% reduction ***Asthma symptom days****: 26% increase****; sleep disruption:*** *increased*	**Moisture** and **smoke** in dwelling - reductions observed
Francisco 2016 EE & ventilation		**Eczema/allergies:** 13% less **Sinusitis:** reduced*	**Volatile Organic Compounds (VOCs):** Reduced
Breysse 2014 EE, repairs, education vs. education only for asthmatics		**Uncontrolled asthma:** 71% less; 23% less with energy/repairs vs. education **Asthma Caregiver Quality of Life:** 31% improvement	**Asthma trigger score:** 13% greater decline in Wx* v. home education homes** **Mold:** 19% greater decline in Wx homes v. education*
Rose 2015 EE, energy & repairs; healthy homes repairs for asthmatics	**Medicaid Costs/yr:** $500 decline in EE homes, $421 all groups **Claims/Month:** declined		
Leech 2004 New energy efficient vs. standard homes		**Asthma symptoms:** reduced **Throat irritation, cough:** reduced	
Jacobs 2016 Window replacement		**Sinusitis:** 18% decline adults **Hay fever:** 5% decline adults **Allergies:** 12% decline children	
Norton 2014 EE, repairs, education homes of asthmatics	**Hospitalizations**: 65% reduction in mean # visits; 28% reduction mean # ED visits		
Howden-Chapman 2007 Insulation in homes of those with respiratory risks vs. control group	**Fewer medical visits** (0.73 OR) **Fewer respiratory hospital admissions** (0.53 OR)*	Reduced **sleeping problems due to wheeze** (O.57 OR) reduced **wheeze** (0.57 OR) Reduced **fair/poor health** cold/flu (0.50/0.57 OR)	Reduced **condensation** (0.16 OR) Reduced **mold** (0.24 OR) Decline **in temperature less than 50°F** Increase **RH less than 75%**

*Weatherization

**Positive impact, marginally statistically significant at p < .10 *Italics indicate some negative findings*

General and Mental Health Benefits From EE

In addition to the respiratory related improvements described above, studies of EE have documented other health improvements and changes in indoor environmental conditions. Key observations are presented below and summarized in more detail in Table 4.

1. **Studies documented improvements in overall health.**
   - The DOE Weatherization Assistance Program (WAP) National Evaluation observed a 48% reduction in the days during the previous month residents reporting their physical health was "not good". (Tonn et al. 2014)
   - A 13% reduction of those reporting their health was "fair or poor" was documented in a second study of single and multifamily energy projects. (Wilson et al. 2014)
   - A New Zealand study of those with respiratory risks documented significantly lower odds of reporting poor health after energy upgrades and greater odds (twice as likely) of reporting good health. (Howden-Chapman et al. 2007)

2. **DOE's WAP National Evaluation showed improvements in mental health.** The report documented a 48% reduction in the number of days in the past month a resident reported poor mental health. Other studies have shown a relationship between reduced fuel costs and improved mental health. (Liddell et al. 2014)

3. **Improvements were documented in studies that evaluated indoor environmental conditions.** Improvements were observed in levels of: moisture/mold, RH, temperature, and volatile organic compounds (VOCs), acetaldehyde, and CO_2. (Pigg et al. 2014; Wilson et al. 2014; Francisco et al. 2016; Norris et al. 2013)

4. **Increases in radon and formaldehyde were documented in the WAP National Evaluation.**
   - A small but statistically significant increase (7%) in radon levels was reported in single family homes that underwent weatherization, while radon levels in the comparison group declined by 15%. (Pigg et al. 2014)
   - One small study of DOE weatherized homes with exhaust ventilation compliant with ASHRAE 62.2 showed the potential to reduce radon when exhaust-only ventilation is operating in homes that had tested above the EPA radon threshold of 4 picocuries per liter (pCi/L) after weatherization work was completed. (Pigg 2014).[2]
   - A second study of weatherized homes with exhaust ventilation compliant with ASHRAE 62.2 also showed a trend toward radon declines in first floor levels and increases in basement levels, although the results were only marginally statistically significant at $p<.10$. (Francisco et al. 2016)
   - Formaldehyde levels increased in weatherized homes (23%), while levels in comparison homes increased by only 11%. (Pigg et al. 2014)

[2] ASHRAE 62.2 is a ventilation standard developed by the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE)

Table 4: General and Mental Health Benefits From EE

Author, Date Comparison group	Health Related Outcomes (Statistically significant at p<.05 unless noted)	
	Occupant Health	Indoor Environmental Conditions
Tonn 2014 EE (Occupant health results based on treatment group only)	**General health:** 48% fewer days not good; 74% reduction days kept from "usual activities"; 44% reduction in days not enough sleep/rest **Mental health:** 48% fewer "not good" days **Thermal stress reduced medical care:** hot 1% cold:2% decline	**Moisture/mold and pests** reduced **RH** increased 1% in winter
Pigg 2014 EE		***Radon*** *increased 7% in study group and declined 15% in comparison group* ***Formaldehyde*** *increased 23% in study group & 11% in comparison group*
Wilson 2014 EE	**General health**: 13% decline fair or poor health **Hypertension**: 14% less	**Moisture** and **smoke** in dwelling - reductions observed
Francisco 2016 EE & ventilation	**Headaches:** 31% decline; 21% greater decline in 62.2 2010 vs. 1989 homes **Mental health score:** improved	**CO_2, formaldehyde, and VOCs:** reduced **Radon:** reduced 32% in first floor; *increased 29% in basements**
Pigg 2014 EE & ventilation		**Radon:** 12% decline **RH:** 2% decline
Leech 2004 New energy efficient homes vs. standard	**Fatigue:** 14% less in energy efficient vs. standard homes	
Noris 2013 EE & home retrofits		**CO_2, acetaldehyde, VOCs, particle counts:** improved ***Formaldehyde****: mixed results*
Jacobs 2016 Energy efficient windows	**Headaches:** 7% decline in children	**Lead dust:** declined 44% floors, 88% windowsills **Comfort:** improved; 22% decline reporting too hot in summer; 33% decline reporting too cold in winter

Italics indicates some negative findings

In addition to the results presented in Tables 2 and 3 from the WAP National Evaluation, the evaluation estimated reductions in carbon monoxide poisonings, and injuries from fires. Due to the relatively rare occurrence of these outcomes, it was difficult to observe changes in such events using the occupant survey data. Hence the evaluation used an alternative methodology relying on other national secondary data to estimate reductions and project health related monetary benefits of weatherization described later in this report. More detailed results from the occupant health survey report are provided in Appendix A; the full reports are available at the DOE website.

Respiratory Related Benefits From Ventilation

Energy program administrators and contractors are increasingly incorporating ventilation into EE projects and programs. Studies of enhanced ventilation provide information about the potential occupant health benefits of such practices. Two studies noted earlier present results of exhaust ventilation when combined with DOE weatherization work. (Francisco et al. 2016, Pigg 2014). In this section, we focus on two Canadian studies that evaluated the installation of energy or heat recovery ventilators (ERVs/HRVs) in the homes of children with respiratory risks. **Studies of ERVs/HRVs document reduced child wheezing and hay fever as well as reductions in formaldehyde and mold spores, which can exacerbate respiratory issues.**

Health Air Study (Kovesi et al. 2009)

This study enrolled Inuit children (under age 6) living in a community with documented risks of respiratory problems. HRVs were installed in 52 homes. Occupant health and indoor environmental conditions were tracked and compared to homes where placebo ventilators were installed. Results (statistically significant at $p<0.5$):

- **Wheezing:** 20% reduced odds of reporting symptoms, compared to children in homes with placebo ventilators.
- **Rhinitis/hay fever:** 12% reduction in odds of symptoms/week
- **CO_2, Relative Humidity:** reduced when compared to control group

INVAIRE Project (Lajoie et al. 2015)

This study enrolled children with asthma living in 83 homes with air exchange rates that were less than 0.3. ERVs were installed in 19 homes; HRVs were installed in 21 homes; and HRVs were repaired or modified in three homes. Results (statistically significant at $p<0.5$):

- **Wheezing:** reduced symptoms
- **Formaldehyde:** 33% reduction
- **Mold Spores, Toluene**: reduced
- ***Nitrogen Dioxide (NO_2)****: 31% increase*

Neither study showed statistically significant changes in health care use.

IV. Monetary Value of Occupant Health Benefits

There is a growing consensus that it is not appropriate to value the occupant health co-benefits of residential energy retrofits at $0 and states are increasingly recognizing such co-benefits in cost-effectiveness practices (e.g., RI, DC, MD, CA, MA, NY). (Woolf et al. 2013; Itron 2014) Studies reviewed in this report, along with previous research on Non-Energy Impacts (NEIs), sometimes referred to as Non-Energy Benefits (NEBs), document such occupant benefits. (Skumatz 2014; Itron 2014; Tonn et al. 2014; Three^3 & NMR 2016)

Monetary estimates of household health benefits range from $3 to over $900/household unit/year for residential energy retrofits (Table 5). Some states have addressed NEIs by incorporating an "adder" to the benefits, which can range from 7.5% to 30%. For example, Oregon incorporates a 2% adder for health related NEIs, while California uses a 20% multiplier. (Skumatz 2015)

Table 5: Examples of Annualized Per Unit Household Health Related Co-Benefits

Estimate ($/unit/year)	Source
$3 - $100; typical $16.50	Skumatz 2014
$27 – limited income insulation/duct sealing	MD 2015 (Potomac Edison, 2015)
$10.46 – low income weatherization $50.32 – low income heating system retrofit/replacement	MA 2011 (Oppenheim 2016; MA Technical Reference 2016)
$937 – low income	MA 2016 under consideration (NMR & Three^3 2016) [discussed below]

In 2016, the Massachusetts Energy Efficiency Advisory Council (EEAC) and the relevant MA utility program administrators (PAs) contracted with Three^3 to assess and monetize the NEIs experienced by recipients of EE services residing in income-eligible single family MA households. (The EEAC is charged with developing a long-term vision for the Commonwealth's energy future to achieve EE savings and maximize the economic and environmental benefits of EE.) The NMR Group, consultants to the MA EEAC reviewed the Three^3 results and recommended that the EEAC accept the results described below. The approach and estimates are currently being considered by the utility program administrators.

Three^3 estimates are based on the WAP National Evaluation discussed in Section III, which assessed changes in occupant health and set forth a methodology to monetize these health and household-related impacts in income-eligible single family homes. (Tonn et al. 2014) In contrast with some previous monetary estimates, the study design relied upon occupant survey responses (pre and post weatherization) and utilized a comparison group to help assess whether changes were due to the work performed. Indoor air quality measurements were also obtained pre and post weatherization. In some cases, the survey approach was unable to capture sufficient data about extremely rare events (e.g., deaths from CO poisoning, fires) to provide robust estimates to develop monetary benefits. For such occupant health benefits, the evaluation used larger surveys of secondary data to provide additional estimates on the likelihood of such rare events. A national

panel of experts reviewed methodologies and assumption, which did not question the validity of the NEIs or the estimated health improvements.

The Three[3]/NMR report recommended that the EEAC recognize eight NEIs based on their estimable and direct impact on the household. Those with health linkages are shown in **bold.** The full report is available on the MA EEAC website, with excerpts are provided below. (Three[3] & NMR 2016)

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

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

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

Estimates were categorized and presented in three tiers. Tier 1 included estimates based on observed outcomes that: could be monetized, were attributable to weatherization, and had highly reliable cost data. Tier 2 and 3 estimates had underlying sound methodologies but may have lacked direct observations of improved health or well-being and/or required relatively more assumptions.

Table 6 presents household and societal NEIs (holistic co-benefits) per weatherized low income unit. The largest benefits are driven by: avoided deaths from thermal stress, CO poisoning, and home fires; avoided hospitalizations and ED visits related to these three areas as well as asthma-related symptoms; and disposable income gains from fewer missed days at work. Table 7 provides a breakdown of the avoided number of deaths, if any, and hospitalizations, ED visits, and physician office visits annually for each health-related NEI (holistic co-benefits) per 1,000 units weatherized. When interpreting these estimates, it important to recognize that they reflect a cold climate. (Regions with warmer climates and more extensive heat days would expect to experience greater heat-related thermal stress than cold-related thermal stress.)

Table 6: Estimated MA Low Income Household and Societal NEIs Per Weatherized Unit Both With and Without Avoided Death Benefit—Annual per Unit

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

*For CO poisoning, the annual NEI is to be applied over the 5-year life of the CO monitor. The remaining NEIs are to be applied annually over the life of the relevant measure (e.g., 20 years for weatherization).

**For home fires, the societal benefit value of $17.87 includes avoided injuries ($17.60) and deaths ($0.27) to firefighters only ($17.60 + 0.27= $17.87). Avoided injuries and deaths to occupants are categorized as a household benefit (as with all other applicable NEIs).

***The value in this column ("Total **W/O** Avoided Death Benefit") has been adjusted to remove not only the household avoided death benefit but the firefighter avoided death benefit of $0.27 reflected in Column C; therefore, this value is not a true sum of Column B + C. The calculation that reflects the adjustment is as follows: $9.77 + ($17.87- $0.27) = $27.37.

Red text indicates the estimate excludes the avoided death benefit

Table 7: Avoided Deaths, Hospitalizations, ED Visits, and Physician Office Visits Annually for Each Health-Related NEI, Per 1000 Units Weatherized

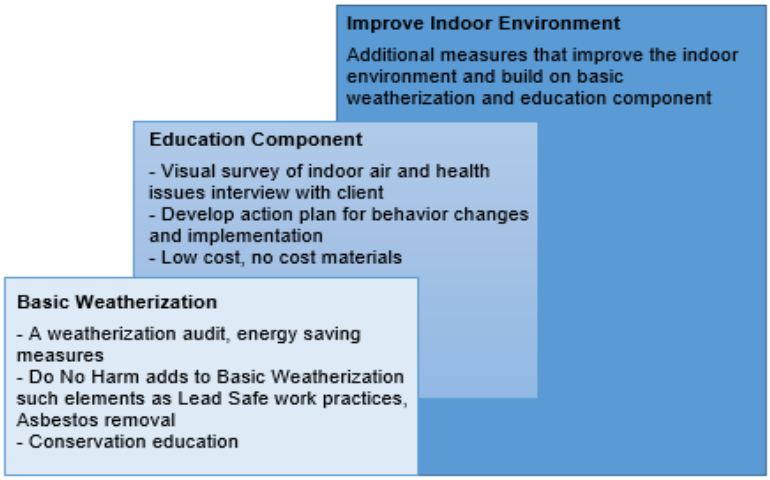
NEI	Deaths	Hospitalizations	ED Visits	Physician Visits
Asthma symptoms	-	9.9 (adult) 4.2 (child)	54.6	-
Cold-related thermal stress	0.05	1.9	7.6	9.5
Heat-related thermal stress	0.01	1.1	23.6	3.2
CO poisoning	0.004	0.07	0.47	-
Fire Injury	0.0087	0.013	0.4	0.25

V. Innovative Energy and Health Programs

As interest in leveraging the expertise and capacity of the EE workforce to address health goals increases, program designers and administrators are responding by creating new models that deliver integrated energy and health services. Key initiatives are profiled below, all in the U.S. except for one in Ireland. Most focus on single family homes; several cover multifamily buildings.

Weatherization Plus Health

Weatherization Plus Health was launched in 2003 by the Opportunity Council, a Community Action Agency (CAA) that operates in Northwestern Washington State. Weatherization Plus Health was developed to give clients added home repairs to address lead hazards, asthma risks and other housing based health threats. The program focused on single family households has operated for over a decade using a three-tiered approach shown below. Agency staff estimate that roughly 15% of clients with young children can benefit from additional measures to improve the home environment beyond basic weatherization, including: enhanced ventilation; moisture repairs; lead hazard repairs; pest exclusion; removal of dust mite habitats; distribution of HEPA vacuums, walk-off mats, and mattress covers.



Courtesy of the Opportunity Council

State legislation directed the WA Department of Commerce to allow state funding provided to weatherization programs to offer this Weatherization Plus Health model statewide to clients with a respiratory disease or who are at risk for falling. The Department of Commerce has developed policy, training requirements and evaluation criteria in support of Weatherization Plus Health. The goal is to broaden the impact and assess the health benefits to clients of this new approach. Weatherization providers like the Opportunity Council are working with local community health clinics to receive referrals and provide this integrated response. Washington State is also exploring a study of Weatherization Plus Health work with high risk asthmatics to track changes in healthcare costs and utilization.

In a recent study of this initiative, the Opportunity Council in partnership with Oak Ridge National Laboratory (ORNL) analyzed and monetized the asthma-related health improvements of health care costs for 49 households receiving one of three interventions (Weatherization Plus Health, Weatherization only, Healthy Homes only). The study found a decrease of $421 in annual asthma-related Medicaid costs and claims across all three groups of home interventions; Medicaid costs declined the most in the Weatherization Plus Health group (See Table 3). (Rose et al. 2015) The initiative recently received a $2.1 million pilot grant to deliver Weatherization Plus Health to eight communities across Washington. The pilot will target 250 households struggling with asthma and COPD. For more information, visit www.nchh.org/Policy/1000Communities/1KCPolicy/WeatherizationPlusHealth.aspx or contact www.buildingperformancecenter.org/contact-us-2/

Green and Healthy Homes Initiative (GHHI)

GHHI was established in 2008, "to break the link between unhealthy housing and unhealthy families by creating and advocating for healthy, safe and energy efficient homes." The program, which is managed by The Coalition to End Childhood Lead Poisoning, operates in a range of locations assisting local programs to braid energy, housing and health resources to provide an integrated home response. The program uses a single point of contact and a comprehensive home assessment tool to develop the appropriate scope of work. GHHI reports reductions in asthma symptoms and hospital use among the clients they serve. In 2016, GHHI partnered with BPI to create the Healthy Home Evaluator (HHE) certification. This credential helps the home performance workforce conduct healthy home assessments to determine conditions that may adversely affect occupant health and safety including asthma triggers, moisture and mold, VOCs, lead-based paint, asbestos, radon, carbon monoxide leaks, fire hazards, and pest management issues. For additional information, visit www.greenandhealthyhomes.org/

ReEnergize Pgh

ReEnergize Pgh launched in 2012 "comprised of local government agencies, energy efficiency professionals, utilities, and environmental and community organizations, and residents working to increase the demand for energy efficiency through partnerships, education and advocacy." The Allegheny County Health Department partnered with Growth Through Energy and Community Health (GTECH) Strategies to administer the Healthy Homes Incentive Program (HHIP) through ReEnergize Pgh to offer homeowners an opportunity to receive funds for investing in whole-home energy upgrades. The coalition leveraged funds from the Allegheny Clean Air Fund to support this new model in 100 single family homes in 14 communities

to reduce energy consumption and improve indoor air quality. For home EE investments of $5,000 or more, HHIP provided up to an additional $2,500 for deeper improvements. The program was profiled in a DOE webinar; see www.energy.gov/sites/prod/files/2015/02/f20/bbrn_072313_Sustainability_Mastermind_Carryer_Summary.pdf.

Healthy Homes Initiative

Initiated in April 2016, the Healthy Homes Initiative is a collaboration between NeighborWorks of Western Vermont (NWWVT) and their local hospital, Rutland Regional Medical Center, to deliver an integrated energy and home rehab program for patients identified by the hospital with asthma, COPD, or home mobility concerns. Asthma referrals will be initiated by the hospital community health worker after a visit to the home of the asthmatic and determination that home repairs or energy upgrades are needed. The program will leverage the expertise of NWWVT's Heat Squad and home rehab programs to design a new integrated service for clients with health concerns in single family homes. As this program is in its initial stages, evaluation results are not yet supplied. For more information, see www.nwwvt.org/2016/06/20/healthcare-and-housing-coalesce-to-help-those-suffering-from-chronic-health-problems.

One Touch: Creating Healthy and Energy Efficient Homes

One Touch® builds local collaborations among energy, health, and housing home visiting programs to increase family access to health and energy services. Partners that "touch" homes use a common home assessment and electronic referral system to identify conditions triggering referrals or changes to the services they deliver. The Vermont Weatherization Program is currently using One Touch during energy audits, connecting families to local health resources for lead, asthma, smoking cessation, and early child development. Over 1,000 single family homes in Vermont's weatherization program have participated and roughly 25% of the assessments have triggered a health or housing referral. The program was developed by Tohn Environmental Strategies and is operating in several locations nationwide. For additional information, visit www.onetouchhousing.com.

Warmth and Wellbeing

The Sustainable Energy Authority of Ireland is piloting the Warmth to Wellbeing initiative, providing energy upgrades to lower income residents living with respiratory problems such as asthma and COPD. All homes that receive energy upgrades will receive an energy rating. This initiative will carry out EE improvements in 400 Dublin homes with grants up to €20,000 per household during 2016. The program provides: attic insulation and appropriate ventilation; wall insulation; and as appropriate, boiler replacement and draught proofing. Eligible individuals must be referred by a health care official, be older than 55, receive a fuel allowance, and live in one of two designated areas. The pilot is planned to continue through 2018 and if successful could be expanded nationwide. More information is available at www.seai.ie/Grants/Warmth-and-Wellbeing/.

Energy Efficiency for All (EEFA)

Focused on multifamily properties, EEFA is a partnership among the National Housing Trust, the Natural Resources Defense Council, the Energy Foundation, and Elevate Energy joined by a large set of allied stakeholders nationwide. Together these organizations collaborate with owners, managers, businesses and advocates, including national groups such as GHHI. EEFA's Network for Energy,

Water, and Health in Affordable Buildings (NEWHAB) initiative works to expand healthy, efficient housing for all. EEFA is working to overcome the obstacles to utility-sponsored investments in multifamily affordable housing by fostering collaboration among housing, utility, and health sectors. More information is available at www.energyefficiencyforall.org.

Energy Programs Consortium (EPC)
In 2015 the EPC released *Using Energy Performance Contracts to Combat Health Hazards in Addition to Financing Energy and Water Efficiency Efforts*, prepared by Clean Energy Solutions. The paper explores using utility savings from energy efficiency upgrades to provide a sustainable funding stream for reducing health hazards (specifically, asthma) in multifamily housing. Contact www.energyprograms.org.

Low-Income Multifamily Energy (LIME) Loan
Capital for Change Inc. (C4C), formerly the Connecticut Housing Investment Fund, is a nonprofit that supports affordable focusing and neighborhood revitalization projects in the state of Connecticut. As a part of C4C's Commercial Loan Program, the LIME Loan provides financing for multifamily residential EE improvements and allows up to 25% of the loan to be used for non-EE improvements including health and safety. See www.chif.org.

These examples showcase programs and initiatives that work with EE programs to add a health assessment, referral, client education, or home repair. Some programs partner directly with health programs in delivering integrated services, while others have engaged health partners in designing the program. In several cases, programs have spawned collaborations among energy, health and housing partners. We can learn from these efforts to inform new models, practices, and partnerships. The Road Map for Action provides specific recommendations to help support and learn from these types of innovative efforts.

VI. A Road Map for Action

Existing research shows us that residential EE can improve occupant health outcomes. Energy programs that fail to consider these household health co-benefits undercount the true value of home EE. Moving forward, a tremendous opportunity exists to build upon what we know by conducting additional research to define best practices and leverage the existing EE programs and workforce to create greater occupant health benefits. Such work should be done in collaboration with health partners, building upon the types of innovative programs profiled in this report. Key actions that will help to further advance this important work are described below.

1. **Share Results: Widely disseminate research results on occupant health benefits and engage energy program regulators to incorporate the occupant health co-benefits of residential energy programs into program design and cost-effectiveness testing.** Guidance on cost-effectiveness testing should recognize the importance of including such benefits. A forthcoming 2017 National Standard Practice Manual on program cost-effectiveness screening will provide guidance on ensuring symmetry for the inclusion of both costs and benefits, including health related impacts from EE investments. In some states, this may

require a greater recognition of the intersection of health and energy.

2. **<u>Support Innovative Programs:</u> Support innovative energy-based programs that are designed to also address occupant health needs by sharing new funding models, work practice standards, evaluation protocols, and encouraging such efforts among energy and health partners.** Nurture new energy and health partnerships through dedicated planning grants and access to technical resources, convene forums to share best practices and create model program tools, and evaluate the results using metrics that resonate with both energy and health partners (energy savings, occupant health outcomes, reduced health care use/costs). Such efforts should involve BPI, which now offers a health credential that builds upon existing workforce training curricula.

3. **<u>Fill Research Gaps:</u> Conduct research to address knowledge gaps**. While the existing research gives us a solid footing that EE can provide occupant health benefits, better information is needed to create energy-based home interventions that also seek to improve occupant health. Priority areas include:

    - **Work with EE and health partners to evaluate programs that offer EE and an enhanced variant providing added home repairs for individuals with asthma/respiratory risks or other housing related health issues**. Many existing US studies do not target high risk health populations. Studies enrolling only individuals with housing related respiratory risks like asthma are more likely to demonstrate health improvements than studies that enroll homes where a smaller percentage of occupants struggle with asthma (e.g., 7% adults nationwide). Studies should focus on lower income individuals who typically have greater health risks. Outcome metrics should include both changes in health symptoms (using a common set of questions to allow comparison across studies) and health care savings (which are easily monetized) to help inform regulatory decisions and engage health partners. The Howden-Chapman study in New Zealand offers a robust design for such future work.

    - **Leverage resources in collaboration with health partners to conduct more robust studies on health impacts using comparison groups.** Many existing US studies do not include comparison groups, which enable researchers to more confidently conclude that improvements are due to EE and not external conditions. Comparison group studies, however, are expensive and opportunities should be explored to comprehensively evaluate integrated EE/health programs by leveraging resources across the energy and health sectors.

    - **Better understand how to prevent unintended consequences of EE, such as potential increases in radon or formaldehyde.** The WAP National Evaluation documented some increases in radon following weatherization work. Two other studies of DOE weatherized homes showed some potential to decrease radon using exhaust ventilation systems compliant with ASHRAE 62.2. (Francisco et al. 2016; Pigg 2014*)* HUD and DOE funded studies are underway to better assess radon exposure post-weatherization and the efficacy of ventilation and other practices to prevent radon increases.

- **Evaluate the health impacts of EE in warmer climates (e.g. air conditioning).** Exposure to extreme heat is responsible for greater hospital and health care use than cold temperatures. However, most studies have focused on northern heating climates. With increasing global temperatures, more households will experience hotter indoor temperatures and the health benefits of efficiency responses to high temperatures are not well understood.

- **Research is needed for market rate homes**. The majority of the studies were conducted in the homes of low income residents. Socio-economic factors have been shown to impact health status and access to care, and these factors could affect the impact of EE measures on occupant health. For example, the National Center for Healthy Housing is undertaking a pilot study of the health benefits of home performance work conducted in Maryland. The project is supported by ecobeco, a leading home performance company. The objective of the study is to create evidence to help motivate clients to procure such services and to engage health care partners to provide some support for this work. The study targets homes with children with non-well controlled asthma.

- **Additional evidence is needed to document occupant health impacts in multifamily units, including changes in health care use.** The majority of the studies were conducted in single-family and mobile homes. To engage both energy and health stakeholders, clear evidence of the health benefits in multifamily properties is necessary. One study that included multifamily housing units showed some health improvements, but did not track health care use. (Wilson et al. 2014) Such studies could provide added background to monetize health co-benefits in cost-effectiveness testing of multifamily programs.

4. **Define and Share Best Practices: Provide guidance and tools to help ensure EE is performed using practices that reduce indoor air quality risks and create healthier homes**. Several studies documented potential increases in indoor air contaminants following EE (e.g., radon, formaldehyde). EPA's "Healthy Indoor Environment Protocols for Home Energy Upgrades" provides guidance to help avoid declines in indoor air quality and other occupant health risks. This resource should be widely disseminated to EE programs and those seeking to create new integrated energy and health home upgrades. As studies provide new insights, guidance should be updated.

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Appendix A: DOE WAP National Evaluation

Additional results from DOE's WAP National Evaluation are presented below. The National Evaluation is the most comprehensive study of a core nationwide US energy efficiency program that evaluated indoor air quality and health outcome measures. Health outcomes were tracked using a pre-tested, national Occupant Survey of a random and representative sample of weatherized single-family homes pre- and post-weatherization, along with a comparison group of homes. In addition, a group of homes that had already been weatherized one year before the treatment group received weatherization services was surveyed during phase 1; this group of homes served as a post-weatherization comparison group. A separate Indoor Air Quality Study was also conducted as part of the WAP evaluation. This study collected IAQ data from a national sample of over 500 treatment and control group homes, with an over sample in EPA radon region 1 areas (i.e., high radon counties). Samples were taken for: CO, radon, formaldehyde, humidity, and temperature pre- and post-weatherization.

Tables A1 and A2 present results showing changes in occupant responses pre and post weatherization (Wx) in the treatment group. The statistical power of the results is also noted with the p values. Only those results that had a minimum p value < 0.05 or are listed. The lower the p-value the stronger the result. A more complete listing of all results is available at in the report.

Table A1: Changes in General Respondent Health Conditions Post-Weatherization

Survey Question	Pre-WX	Post-Wx	Change
Number of days physical health not good last month (0-30)	10.3	5.4***	-48%
Number of days mental health not good last month (0-30)	7.1	3.7***	-48%
Number of days did not get enough rest or sleep last month (0-30)	11.7	6.6***	-44%
Number of days felt very healthy and full of energy last month (0-30)	18.5	8.9***	-52%
Number of days kept from usual activities last month (0-30)	15.28	4.0***	-74%

*** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment

Table A2: Changes in Specific Health Conditions Post-Weatherization

Survey Question	Pre-WX	Post-Wx (1)	Change
Asthma emergency department visits past year	15.8%	4.3%*	-11.5%
Persistent cold symptoms lasting more than 14 days last year (% yes)	21%	12%***	-9%

*** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment

Table A3: Physical Condition of Homes Pre- and Post-Weatherization (Means)

Survey Question	Pre-WX	Post-Wx	Change
How often home too drafty (1= all the time, 4 = never)	2.86	3.60***	26%
Outdoor noise (1=great deal, 4= none at all)	2.07	2.37***	14%
How infested is home with cockroaches, other insects, spiders (1=extremely infested, 5=not infested at all)	4.19	4.37***	4%
How infested is home with mice (1=extremely infested, 5=not infested at all)	4.61	4.73*	3%
Frequent mildew odor or musty smell (1=yes, 0=no)	.30	.21***	-9%
How often have observed standing water in home (1= never, 5=always)	1.60	1.44**	-10%
Have seen mold in home (1=yes, 0=no)	.28	.19**	-9%

*** p<.001; ** p <.01; * p<.05; (1) Pre-Wx treatment vs. Post-Wx Treatment