Protecting the Health of Vulnerable Populations with In-Home Energy Efficiency: A Survey of Methods for Demonstrating Health Outcomes

Sara Hayes and Ronald Denson Jr.

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© American Council for an Energy-Efficient Economy
529 14th Street NW, Suite 600, Washington, DC 20045
Phone: (202) 507-4000 • Twitter: @ACEEEDC
Facebook.com/myACEEE • aceee.org

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About the Authors

Sara Hayes manages the Health and Environment Program at ACEEE. She oversees a research team focused on strategies and opportunities to use energy efficiency to reduce pollution and improve human health. An attorney, Sara serves on the Environmental Protection Agency's Clean Air Act Advisory Committee.

Ronald Denson Jr. conducted analysis and research on the health and environmental benefits of energy efficiency investments in the United States during his tenure with ACEEE. His work supported policymakers, advocates, and ACEEE programs in their consideration of energy efficiency policies and programs that addressed health and equity.

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Executive Summary

KEY FINDINGS

- Although all the programs we studied try to document health impacts, there was no single standard method for tracking them.
- We identified 23 frequently measured health indicators. However, on average, each program tracks only 4 or 5 indicators, and more than half the programs track 3 or fewer.
- Almost every program in our set conducts a pre-intervention environmental health assessment.
- There is no established standard of proof or rigor used to demonstrate a relationship between a program intervention and a health outcome.
- Programs could take a number of steps to better assess and communicate their health impacts, including adopting a set of standards or a framework for decision making about what information to collect and how to report it, and forming cross-sector partnerships to bring in health care expertise and resources to program delivery.

The buildings people work and live in can dramatically influence their health. Poorly sealed building envelopes allow pests, moisture, and air pollution to enter interior spaces; these can harm respiratory health by introducing allergens, mold, and disease. Leaky windows and poor insulation can lead to drafts and extreme temperatures in homes during summer and winter months. These temperature variations can trigger asthma attacks and exacerbate other respiratory illnesses. Even inefficient and malfunctioning appliances can degrade air quality through incomplete combustion or improper venting. Together, these pollutants and inadequate housing conditions contribute to some of the leading causes of death in the United States: cancer, chronic lower respiratory diseases, heart disease, and stroke.

Disproportionately high numbers of low-income and black families live in homes with inadequate conditions. These communities also tend to face higher local exposure to air pollution. In turn, many of the chronic diseases exacerbated by inadequate housing conditions and indoor air pollution occur at higher rates among these communities. For example, black children experience asthma at more than twice the rate of white children.

Energy efficiency programs can make homes safer and healthier while directly benefiting vulnerable families financially. Efficiency-related building upgrades can improve housing conditions, reduce exposure to air pollution, and strengthen the financial security of families by lowering energy bills (and health care costs). Energy efficiency programs may also address other basic building safety measures, such as handrails and smoke, radon, and carbon monoxide detectors. These measures save lives.

Recognition of the important links between energy efficiency measures and health outcomes is on the rise. This growing awareness, paired with an ongoing evolution of the health care sector, provides an unprecedented opportunity for energy and health professionals to work in tandem. Home-based energy efficiency interventions align well with the shift toward

preventive health services and the increased focus on addressing the social determinants of health.

Energy efficiency programs have historically been largely operated by energy utility providers, which rarely prioritize health outcomes and function largely siloed from public health institutions. Knowledge and technical gaps between energy- and health-sector advocates may still pose a significant barrier to action. The following developments could benefit program implementers, health care professionals, and community activists who wish to fully leverage existing efficiency program infrastructure:

- Identification of program interventions that have the greatest impact on health
- Clear evidence that program interventions are achieving health benefits
- Evidence that families who most need these services will see benefits
- Partnerships between key decision makers bridging the energy and health care sectors
- Mechanisms to braid, blend, and/or layer funding streams allocated to energy efficiency programs with funding streams allocated for improving public health

Measurements and documentation of participant outcomes are critical to all of the objectives listed. Program implementers that track, measure, and document health outcomes of participants can directly achieve the first three items. Documenting program health impacts will also help attract interest from health care partners and demonstrate the value of the programs to potential funders—effectively supporting work to achieve the last two objectives.

This study looks at programs across the United States to identify the methods they are using to measure and document their health impacts. For this report, we have compiled evaluations of methods used by 63 programs. This group includes energy efficiency or weatherization programs as well as home health or green home programs designed explicitly to improve the health of building occupants. Regardless of whether the stated goal of the program is health or energy savings, we included it in our data set if it includes installation of in-home energy efficiency measures.

All of the programs in our data set offer multiple types of interventions. The assessments of health impacts generally evaluate the impact of a program's entire engagement with a participant, including elements such as education and behavior change, installation of specific technologies, and repairs to malfunctioning appliances. These are not studies documenting the health impacts of specific technologies; rather, they are evaluations meant to assess how each bundle of services affects the welfare of the family receiving them.

In addition to positioning programs to take advantage of the opportunities provided by the Affordable Care Act's new health care paradigm, tracking the health outcomes of a weatherization plus health program can particularly benefit the overburdened populations served for many other reasons. Tracking health outcomes can produce actionable data that can be used to design and implement programs that address the unique needs of the communities they serve. For example, if a community seeks to reduce the number of emergency room visits for children experiencing asthma attacks, a program can be designed to identify and mitigate in-home asthma triggers. A referral system can then be established

so that health care providers connect patients to that program. Data on health outcomes can also help programs avoid unintended adverse effects, make a program more competitive for limited funding, and attract partners that can help support and expand the program.

Introduction

Increasing recognition of the tie between efficiency measures and health, combined with the current restructuring of the health care sector, provides an unprecedented opportunity to change the way the energy and health sectors interact. In-home energy efficiency programs can address social determinants of health such as housing conditions, economic security, and environmental issues.[1] The Affordable Care Act has put the health care industry on the verge of a major transformation, shifting the financial model so that preventive services that address these social determinants of health are increasingly valued and success is measured on the basis of health outcomes rather than the volume of office visits. As the outside air worsens with climate change, ensuring healthful indoor spaces will become even more important for sustaining the health and well-being of vulnerable populations.

Energy efficiency programs can do a great deal to protect and improve public health. However many important questions remain. What combination of efficiency measures has the greatest effect on health? How big is the impact? Whose health is most affected? The answers will help health departments, hospitals, utilities, and program administrators design home-based energy efficiency programs and approaches that maximize health benefits and make the best use of limited resources.

Measuring and documenting the health impacts of these programs helps ensure that resources are used effectively and that the families most in need are seeing benefits. Documenting health outcomes provides actionable data that program administrators can use to identify design and implementation approaches that are particularly successful in the communities they serve. Documentation also provides an opportunity to track the welfare of participants and avoid unintended outcomes.

Demonstrating results can help attract partners that can support and expand a program. For example, utility-run programs might find supportive partners in the health care community if they can show health benefits. Further, being able to demonstrate specific health outcomes can position a program to leverage dollars earmarked for preventive approaches to health care. Successfully demonstrating positive outcomes can help make a program a priority when competing for limited funding. Figure 1 walks through a theory of change describing what is needed to leverage the nationwide network of existing energy efficiency programs as an in-home preventive health care strategy so that we can protect the health of our most vulnerable populations.

By measuring the health impacts of their programs, implementers can achieve the first three steps of the "What's Needed" box in figure 1 below: identification of interventions with the greatest impact on health, persuasive evidence that the program has health impacts, and evidence that vulnerable community members are seeing health benefits from the program. These results will also help to attract interest and build partnerships with health care partners and demonstrate the value proposition of the programs to potential funders.

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[1] Read more about the social determinants of health here: www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health (ODPHP 2018).

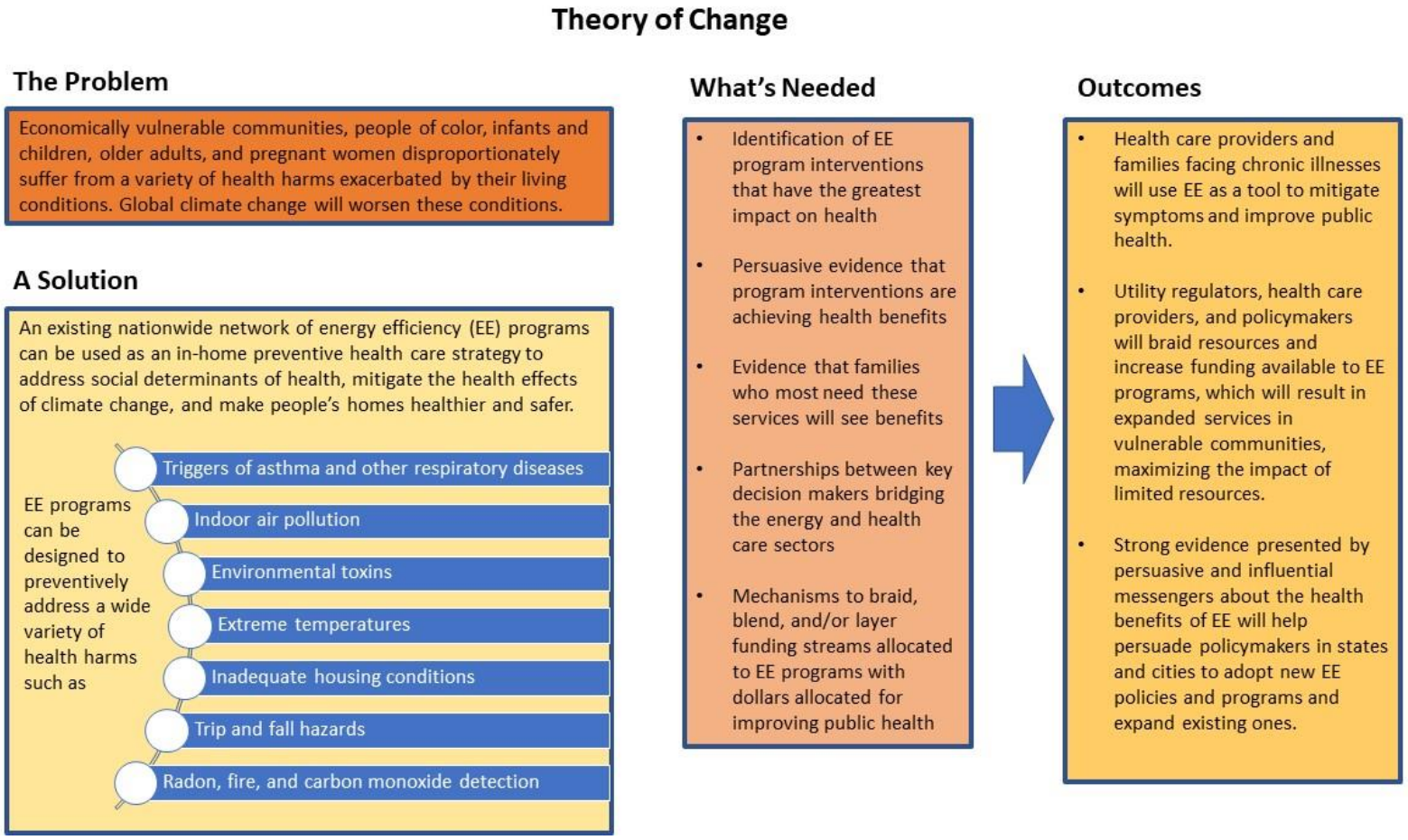

Figure 1. Leveraging energy efficiency programs to protect public health

Background

HEALTH IN THE BUILT ENVIRONMENT

The buildings people work and live in can dramatically impact their health. In the United States, 53% of the building stock is more than 35 years old (Zhao 2017). In older buildings, equipment and systems begin to malfunction, exposing occupants to health and safety threats. In some cases, buildings were constructed with hazardous materials such as lead and asbestos (Mayo Clinic 2016, 2017). For example, in approximately 4 million US homes, children, who are particularly vulnerable to developmental damage from lead, are being exposed to high levels of this heavy metal (CDC 2017; Mayo Clinic 2016). Buildings can also have high levels of radon, which typically seeps in through the foundation and is the second leading cause of lung cancer in the United States (NCI 2011).

A building envelope is the outer shell that separates occupants from outside elements, keeping the inside of a building dry and controlling the indoor temperature. Poorly sealed building envelopes allow pests, moisture, and air pollution to infiltrate. All of these can harm respiratory health through mold growth, allergens, and disease. Leaky windows and poor insulation can lead to cold drafts and extreme temperatures in a home during summer and winter months. This can trigger asthma attacks and exacerbate other respiratory illnesses (AAFA 2017; ALA 2018). Inefficient and malfunctioning appliances may degrade air quality through incomplete combustion or improper venting. In poorly sealed buildings, pollution from coal and other fossil fuels used to generate electricity can enter. These pollutants contribute to four of the leading causes of death in the United States: cancer, chronic lower respiratory diseases, heart disease, and stroke (ACEEE and PSR 2015).

Low-income and black families live in homes with inadequate conditions at disproportionately high rates. According to US Census data, low-income households make up 37% of respondents but represent more than half (56%) of the households with inadequate housing conditions (USCB 2017). Black families are 60% more likely than white families to be living with inadequate housing conditions (USCB 2017).[2] Many of the chronic diseases exacerbated by these conditions disproportionately fall on certain populations. Low-income and racial minority populations suffer from higher rates of asthma, heart attack, stroke, and high blood pressure (Brown 2012; Akinbami et al. 2012; Go et al. 2013; CDC 2016; Oates et al. 2017). Black children experience asthma at more than twice the rate of white children (CDC 2018).[3]

These populations are also disproportionately exposed to air pollution. A recent study found that low-income communities and people of color are exposed to particulate pollution at levels that are 35% and 28% higher, respectively (Mikati et al. 2018). The same

[2] ACEEE calculation using US Census data. A discussion of the conditions that are considered in determining whether housing is inadequate can be found here: census.gov/content/dam/Census/programs-surveys/ahs/publications/HousingAdequacy.pdf (Eggers and Moumen 2013).

[3] In 2016, the asthma rate for white children was 7.1% compared to 15.7% and 12.9% for black and Puerto Rican children, respectively.

study found that black households were exposed to particulate pollution burdens that are 54% greater than average.

Millions of Americans living in unhealthy housing also face a high energy burden and struggle to meet their basic energy needs (Drehobl and Ross 2016). *Energy burden* is a household's total annual energy spending (electricity, gas, and/or other heating fuel) as a percentage of total annual gross household income. A joint research report by the American Council for an Energy-Efficient Economy (ACEEE) and Energy Efficiency for All[4] found that low-income (those with an income at or below 80% of the area median) and minority households experienced higher energy burdens than the average household in the same city (Drehobl and Ross 2016). Difficulty paying bills can affect more than lights. Energy insecurity and high energy burdens affect a household's ability to afford quality housing or pay for food and medicine. Having limited funds for a healthy diet, health care, and a comfortable home also increases the risk of chronic disease for struggling individuals and families (Hernández 2016).

ENERGY EFFICIENCY'S IMPACT ON HEALTH

Measures that improve energy efficiency can also make homes safer and healthier (Francisco et al. 2016; Leech, Raizenne, and Gusdorf 2004; Wallner et al. 2015; Wilson et al. 2014). Saving energy improves housing conditions, reduces exposure to air pollution, and improves financial security of families.[5]

Energy-efficient buildings are sealed (and ventilated) to prevent ambient air pollution and excessive moisture from entering through cracks in attics, basements, windows, and other openings. Residential energy efficiency programs frequently address air penetration around windows as part of measures to seal the building envelope. Because energy-efficient buildings are well insulated, climate-controlled air stays at a temperature that is comfortable for occupants throughout. Enhanced ventilation can improve the indoor environment, reducing airborne contaminants such as particulate matter, mold, and pest excreta. These programs also address basic safety concerns such as smoke, radon, and carbon monoxide detectors and handrails. These measures save lives.

Changes to the living environment can reduce asthma attacks and mitigate the symptoms of other respiratory illnesses such as chronic obstructive pulmonary disease (COPD) and asthma (Breysse et al. 2011; Breysse et al. 2014; Osman et al. 2010). Figure 2 illustrates some of the ways energy efficiency can address common asthma triggers.

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[4] For more information about Energy Efficiency for All, see www.energyefficiencyforall.org/.

[5] Two seminal publications summarize efficiency's health co-benefits: the US Department of Energy (DOE) report *Home Rx: The Health Benefits of Home Performance* and E4theFuture's white paper *Occupant Health Benefits of Residential Energy Efficiency* (Wilson et al. 2016; E4theFuture 2016).

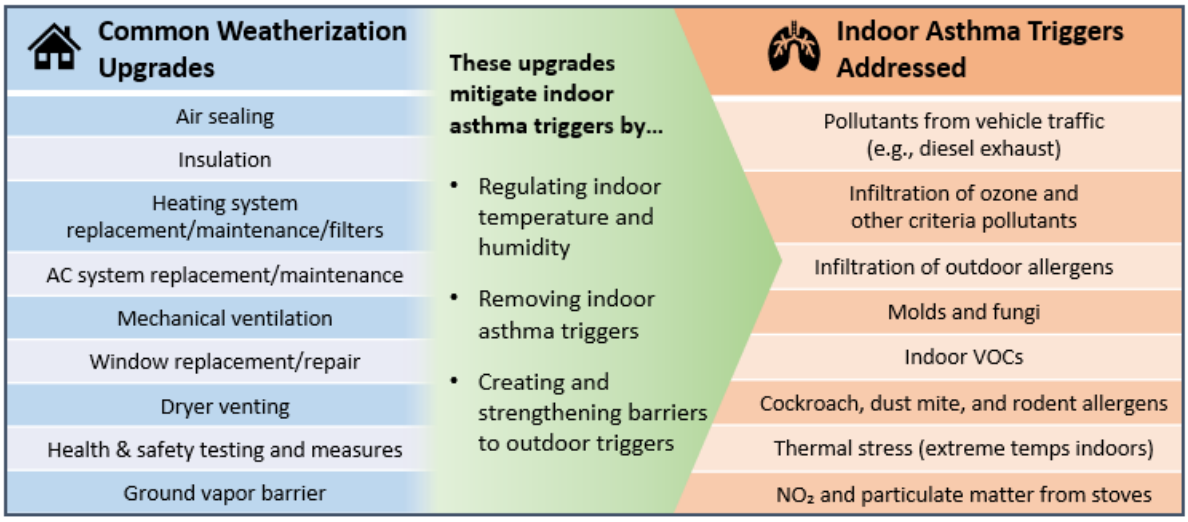

Figure 2. Common weatherization upgrades and asthma mitigation benefits

Studies have shown that energy efficiency improvements can have a number of other health benefits (Lloyd et al. 2008; Ahrentzen, Erickson, and Fonseca 2016). For example, an Australian study found that residents of inefficient homes were approximately 50% more vulnerable to heat stress during a heat wave than were residents of efficient homes. This study estimated that energy efficiency upgrades would reduce this risk to 4% (Alam et al. 2017).

The documented health benefits of residential energy efficiency in 25 recent studies include the following (E4theFuture 2016):

- Reduced respiratory symptoms
  - Asthma
  - COPD
  - Bronchitis
  - Nasal allergies
- Examples of other reduced health risks
  - Colds, rhinitis
  - Headaches
  - Heart disease
  - Hypertension
  - Sinusitis
  - Fatigue
  - Mental disorders
  - Lung cancer (estimated on the basis of exposure reduction)
- Reduced emergency department visits or hospitalizations for asthma and other respiratory diseases
- Improved indoor air quality
  - Moisture
  - Condensation
  - Volatile organic compounds (VOCs)

- Moisture and mold
- Dust allergens
- Particulates
- Formaldehyde
- Radon

Energy efficiency can further protect public health by reducing air pollution from power plants. Lowering the amount of energy we waste reduces the need to burn coal and other fossil fuels to generate electricity. Those reductions in air pollution lead to significant gains in human health. A recent ACEEE analysis found that a moderate combination of energy efficiency strategies, if adopted nationwide, would result in more than six lives saved each day, up to $20 billion in avoided health harms, and nearly 30,000 fewer asthma episodes each year (Hayes and Kubes 2018).

Residential energy efficiency programs also lower energy costs. A study of a federal energy efficiency program found that post-weatherization homes experienced a 20% decline in the number of older adults reporting that it was hard or very hard to pay energy bills (Tonn et al. 2014).[6] The report also found that households were better able to afford and follow prescriptions, see their doctors, and pay health-related bills.

ENERGY EFFICIENCY PROGRAMS

Programs offering residential energy efficiency operate nationwide and are run by utilities, state energy offices, public health departments, community-based organizations, and more. In 2017 alone, utilities spent $7.9 billion on energy efficiency programs for customers (Berg et al. 2018). The biggest and most well-known energy efficiency program, the federal Weatherization Assistance Program (WAP), serves approximately 35,000 homes per year nationwide and has been operating since 1976. It has served over 7 million families in that time (DOE 2018b). Table 1 shows the types of energy efficiency measures offered by WAP and how often they are employed. In a survey of over 800 WAP participating households, over 30% of respondents reported improved health after weatherization (Tonn et al. 2014).

[6] We use the term *weatherization* here because this is how the data are reported in the source publication. Although some programs and practitioners may make a distinction between a weatherization program and an energy efficiency program, we use the phrase *energy efficiency* to be interchangeable with *weatherization*.

Table 1. Prevalence of energy efficiency measures in WAP participant homes

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

* Energy-consuming appliances and fixtures that are not part of the HVAC systems. *Source:* Tonn et al. 2014.

Although energy efficiency programs tend to offer common elements, the combinations of measures offered across programs vary considerably. Some programs may focus only on the building envelope, while others offer only replacement of heating systems. The variability across buildings and individuals is another complication. The age of a building, its type (multifamily versus single family), and the climate zone it is located in are all factors that can affect the way an energy efficiency measure impacts the occupants. Furthermore, the occupants themselves vary substantially. Age, socioeconomic status, race, and other factors affect a person's susceptibility to certain kinds of diseases. For example, children, older adults, and pregnant women are more vulnerable to certain health harms. Black and Puerto Rican families confront childhood asthma at much higher rates than white families. These variables offer an opportunity to design energy efficiency programs to maximize health impacts for the most vulnerable and highest need households. Programs can be designed to address common substandard housing conditions and target those disproportionately burdened by health harms. This study looks at programs across the United States to identify the methods they are using to measure and document their health impacts. We then make recommendations to help ensure that even more programs take advantage of the energy and health intersect to promote healthy communities and more-equitable outcomes.

Research Approach

Our approach compiles evaluations of a wide range of programs that install in-home energy efficiency measures. We include programs identified as energy efficiency or weatherization as well as home health or green home programs designed to improve the health of building occupants—as long as those programs include energy efficiency as part of the package of interventions they offer.

All of the programs in our data set offer multiple types of interventions. The assessments of health impacts included herein largely evaluate the impact of a program's entire

engagement with a participant. This might include education and behavior change, installation of specific technologies, repairs to malfunctioning appliances, and so on. These are not studies documenting the health impacts of specific technologies; rather they are evaluations attempting to assess how a bundle of services affects the welfare of the family receiving them.

To collect data, we conducted a literature review of studies measuring the health impacts of energy efficiency in buildings across the nation. We identified 25 published studies summarizing health impacts of programs and projects offering a variety of energy efficiency measures. The studies in our set were all published in 2005 or later and evaluated US-based programs. Next, we contacted 49 additional programs to solicit information on what, if any, methods they use to measure and document health outcomes. These programs were identified through a call for nominations of programs that both protect health and save energy.[7] Once we identified the programs that are tracking health outcomes, we sought more detailed information by conducting phone interviews with administrators of those programs.

We combined data from the studies in our literature review with the practices and outcomes reported to us by programs and through interviews. Using this, we identified the types of health outcomes being measured by programs and the methods used to identify those outcomes.

All programs in our study group are tracking energy, environmental, or health outcomes before and/or after intervention. This report summarizes methods being used in 63 weatherization plus health programs,[8] 25 of which are in published studies. The fact we were able to identify 63 programs and studies attempting to track health impacts does not mean documenting health impacts is standard practice or that these data are readily available. ACEEE conducted a nationwide solicitation of programs aiming to save energy and improve health, requesting documentation of health and energy outcomes. Of the 50 programs that responded, only 2 produced data documenting the health outcomes of their efforts (Denson and Hayes 2018). Furthermore, utility-run energy efficiency programs are in effect throughout the United States, and documenting health outcomes is not standard practice. In a recent look across states, we identified only 18 states where accounting for health benefits is permissible for purposes of determining the beneficial outcomes of an energy efficiency program (Kubes 2018).

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[7] In March 2018, ACEEE conducted a research project, with a companion report entitled *The Next Nexus: Exemplary Programs That Save Energy and Improve Health*, to identify the common and best practices of energy efficiency programs that aim to simultaneously increase energy savings and improve occupant health in buildings (Denson and Hayes 2018).

[8] Throughout this report we refer to the 63 examples in our data set as weatherization plus health programs. In fact, some of the studies in our data set document outcomes of efforts that would be more accurately described as projects, e.g., the health impacts of a single multifamily building, rather than an ongoing program offered across multiple buildings. In addition, the programs in our data set are not always referred to as energy efficiency programs. For example, some programs might be identified as in-home asthma interventions or described as a healthy homes or green program. If a program offered energy-saving interventions, we included it in our data set, even if energy efficiency was not the primary motivation for the program.

All programs and studies in our set are listed in Appendix A. In the following sections, we summarize program approaches to measuring health impacts, provide observations, and make recommendations based on our findings.

Findings: Program Approaches to Measuring Health Impacts

Programs are tracking a wide range of health outcomes with no standardized method in place. Some programs directly measure human health and wellness. Others track indirect measures of health, or "proxies" (such as environmental conditions or the presence of technologies that can affect health), that provide an indication of likely health outcomes. In the remainder of this section, we discuss methods that program implementers use for collecting these data and the types of data collected and provide illustrative examples summarizing the approaches used by a select subset of programs.

DATA COLLECTION METHODS

We categorized the approaches for measuring and tracking health outcomes attributed to weatherization plus health programs into five methods:[9]

- *Survey or interview*. Privacy protections and lack of access can be barriers to obtaining medical records. Surveys and interviews are a way that programs can collect self-reported information about direct human health outcomes. These methods involve presenting a series of questions in person, by phone, online, or in a paper format. It can be conducted with an individual or with multiple people (i.e., a focus group). Typically, a program point of contact—an educator, coach, or other professional—will facilitate the questionnaire or interview, which consists of self-reported status updates. Program participants might be asked about the frequency or severity of symptoms, days of missed work or school, visits to health care providers, urgent care use, hospitalizations, temperature, and presence of certain technologies as well as their comfort and state of mind.
- *Modeling and estimates*. Some programs estimate health impacts by drawing conclusions based on known relationships. For example, a program might track energy usage before and after an intervention. These energy savings can be used to calculate air pollution avoided from reduced fossil-fuel production at power plants. Avoided pollution can then be used to estimate public health benefits.[10] The value of health and environmental benefits may also be extrapolated on the basis of results reported from other programs or studies. For example, a program might mandate air sealing in all participating households. Rather than visually verifying the air sealing

[9] We have attempted to define these methods on the basis of observations of practices across multiple programs. However, because of the great degree of variability across programs, we have applied these definitions broadly. We have employed subjective judgments to assess whether an approach described by a program fits into one of the categories. Not every approach fits squarely into one of these categories.

[10] The Environmental Protection Agency's Avoided Emissions and Generation Tool (AVERT) and Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) are examples of tools that can be used to estimate public health benefits of energy savings programs and policies. More information is available here: www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert and here: https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool.

was completed, the program administrator might rely on a report that the work was done and draw on studies about the health effects of air sealing to extrapolate health impacts.

- *Environmental testing*. Environmental testing is the measurement of certain conditions in the living space that provide an indication of the healthfulness of the environment. It includes air quality testing for particulate matter, radon, carbon monoxide, nitrogen oxides, and VOCs. It also includes testing of ventilation rates, temperature, humidity, and mold.
- *Visual inspection*. This category includes approaches where someone affiliated with a program performs a visual inspection of a home. The inspection might identify the presence or absence of certain technologies such as smoke detectors and working thermostats. Visual inspections might also be used to identify health risks such as pests, moisture or mold, injury risk, malfunctioning appliances, or other deficiencies that could threaten health and/or safety.
- *Medical records*. Health outcomes can be documented using information from medical records and might include information about the health status of a program participant. These records may include test results, the opinion of a medical professional, symptoms or diagnoses observed or recorded by a medical professional, and visits to hospitals, emergency rooms, and doctors.

Of the 63 programs and studies in our data set, 34 conduct some form of survey or interview related to health; 22 produce results based on modeling or bill data. Environmental testing and visual inspection are used by 16 and 14 programs, respectively. Only 2 programs out of 63 claimed to use medical records. Figure 3 shows this distribution.

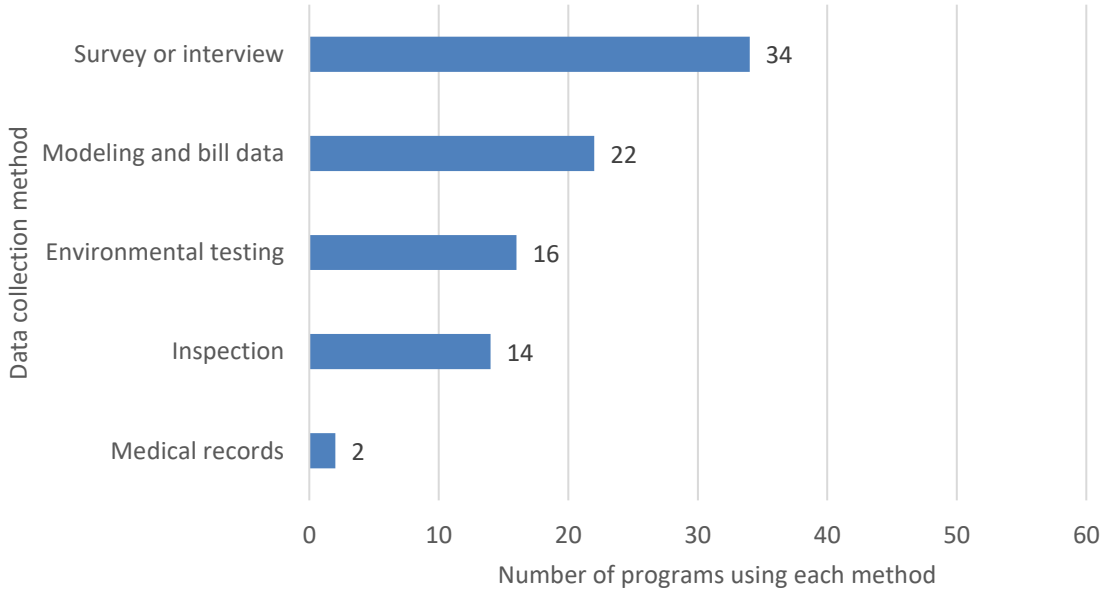

Figure 3. Methods of data collection for measuring health impacts

TIMING OF DATA COLLECTION

Energy efficiency programs often have several "touches" with program participants, including an initial audit or assessment of needs, performance of work or services, and a post-work follow-up or check-in. These represent three major phases of a program's engagement with participants (figure 4). Programs can also be designed to include additional touches, e.g., asthma education and other health-related coaching and referrals that initiate contact with other service providers.

Figure 4. Program engagement with participants

Each of these interactions provides an opportunity for data collection. In this section, we provide discussion of the two primary times data are collected: at the beginning (pre-intervention) and at the end (post-intervention).

Pre-Intervention: Initial Audit or Baseline Assessment

An initial audit or baseline assessment can identify where the greatest health gains might be found and can be used to determine whether health improvements have been made once a home intervention is complete. These pre-assessments are referred to by a variety of names such as "Home Health Assessment," "Environmental Health Assessment," or "Home Energy Audit." These evaluations may involve a survey of program participants, including (but not limited to) questions about the frequency of calls to a primary care doctor, visits to the emergency room, or the regularity of asthma, COPD, or other respiratory symptoms. These evaluations frequently identify issues in the home pertaining to air quality, the presence of mold, extreme temperature swings, pests, and more. Assessments often focus on the condition of the home and the performance of its energy systems. These assessments commonly identify health and safety issues.

Virtually every program in our set conducts a pre-intervention assessment, although no standard set of questions is used.[11] The method for administering the baseline assessment also varies. In some cases, an energy auditor, a person trained to perform an energy assessment, might use special equipment such as a blower door,[12] infrared camera,[13] or air-quality testing equipment. In other examples, a community health worker or a nurse might

[11] Three programs did not provide a response to this question. One program did not perform a pre-intervention assessment as it provides new housing (i.e., there was nothing "pre" to assess). All remaining programs conduct some form of pre-assessment.

[12] A blower door is a machine used to locate air leakage sites in a building envelope.

[13] An infrared camera provides thermal imaging that can detect heat loss and reveal missing insulation, HVAC air-flow and equipment issues, radiant heating malfunctions, and compromised roofing.

assess the home for asthma triggers or other potential health harms. Sometimes participants provided all the information themselves through an online form or survey.

> A Vermont-based program called One Touch includes a qualitative baseline survey that asks participants about several energy, health, and safety issues, including household members with respiratory illnesses; lead risk; leaky windows, pipes, or roofs; nonfunctioning smoke or carbon monoxide detectors; and old, inefficient appliances and lighting. The survey also asks about other energy use and heating concerns such as an unvented combustion heater, frequently used space heater, and closing off rooms to reduce energy usage.

Examples of pre-assessment questionnaires are available at aceee.org/research-report/h1901.

Post-Intervention Assessment and Verification of Results

A post-intervention assessment or verification of results happens once energy efficiency measures have been installed and upgrades to the home have been completed. Collecting data post-intervention can be particularly valuable to demonstrate impact. This is especially true when those results are combined with a pre-assessment. Together, these two assessments can be used to verify that a change in health or living conditions has occurred.

The rigor of approaches used to verify health outcomes attributable to programs and the methods for reporting vary widely. Some of the studies we looked at met a high degree of rigor, having been peer reviewed and published in academic journals. Other programs reported their results on a website or in a self-published study. A few reported tracking health outcomes and were willing to describe their methods but did not share their results. In our set, post-intervention assessment or verification of results was almost a uniform practice; 60 out of 63 programs conducted some form of assessment.[14]

> The Baltimore-based Green and Healthy Homes Initiative (GHHI), for example, conducted a study to assess the asthma status of more than 200 children in households that received the intervention. A follow-up phone survey was conducted six months after the intervention took place. Staff collected demographic information including race, gender, and socioeconomic status. The GHHI staff asked about the status of the participant's uncontrolled asthma in the past six months, health care utilization due to asthma, and days missed of school or work due to asthma (Norton and Brown 2014).

INDICATORS USED TO DOCUMENT HEALTH OUTCOMES

Health indicators are specific measurements or outcomes used to document or infer a health outcome. Measurement of a change in symptomatic asthma days for a program participant, the amount of mold in a home, and whether there is an operational carbon monoxide detector are types of indicators that tell us something about the healthfulness of program participants or the environment they live in. Later in this section, we will discuss 23 indicators that programs are using. We start by creating a framework to group health indicators into three broad categories.

[14] One program did not respond to this question; two programs did not conduct an assessment.

Human health and wellness. This category includes indicators that directly measure human health. These kinds of data might come from medical records documenting instances of illness or other physical conditions, interviews, and surveys of program participants, for example.

Indoor environmental quality. This category includes both quantitative and qualitative measurements of indoor environmental conditions that can affect the healthfulness of a home. It includes measurements of things such as particulate matter, humidity, carbon monoxide, and so on as well as visual observations of things such as mold, cockroaches, and other pests.

Presence of technologies. The presence of certain technologies can serve as a proxy for assessing whether a program has likely had an impact on the health of residents. For example, the installation of a humidifier or air ventilation system can have a dramatic effect on a person's health. Similarly, verification and installation of smoke, radon, and carbon monoxide detectors are common practices that can save lives.

Some programs track indicators from several of these categories, while others track only a single outcome. Of the 63 programs in our set, more than half (36) track one or more indicators that fall into our human health and wellness category. Roughly half (32) are tracking one or more indoor environmental quality indicators. The tracking of technologies to indicate health-related outcomes (24) is used less frequently. Figure 5 shows this distribution.

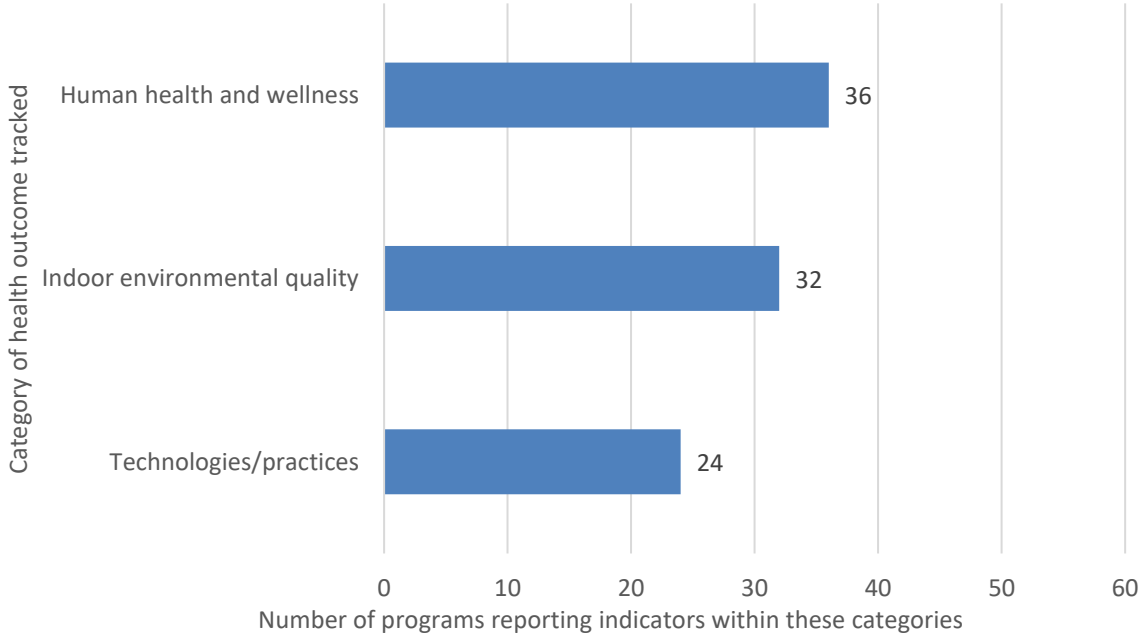

Figure 5. Categories of health outcomes tracked, by number of programs

A vast body of experience and research exists around evaluation of the energy- and technology-related outcomes of utility-run efficiency programs that must document

performance to justify program spending. This work is commonly referred to as evaluation, measurement, and verification (EM&V).[15] This is a set of procedures used to gauge the effectiveness of energy efficiency interventions (DOE 2018a). EM&V has a long history linked to energy efficiency going back to the 1970s. Several EM&V protocols have been developed to standardize practices for quantifying energy savings.

Because ACEEE and other organizations have written extensively on the EM&V of energy efficiency programs in the past, we have opted to focus on the indicators that fall within the categories of indoor environmental quality and human health and wellness for the remainder of this report. Within these two categories, we identified 23 indicators collected by programs in our set, as follows:

- Human health and wellness
  - Days of school missed
  - Days of worked missed
  - Hospital admissions
  - Emergency room visits
  - Visits to the doctor
  - Calls to the doctor
  - Asthma symptoms
  - Uncontrolled asthma
  - Other respiratory illness
  - Comfort
- Indoor environmental quality
  - Tobacco smoke
  - Rodents
  - Cockroaches/insects
  - Pet dander
  - Water drippage/condensation/dampness
  - Mold
  - VOCs
  - Radon
  - Temperature
  - Humidity
  - Carbon dioxide/ventilation rates
  - Carbon monoxide
  - Particulate matter

This group of 23 is not intended to represent every possible indicator that might be measured; rather, we selected indicators that were measured by multiple programs and that appeared frequently in our literature review.

[15] Readers can find more information about EM&V here: aceee.org/topics/evaluation-measurement-and-verification-emv (ACEEE 2018).

Figure 6 illustrates that among a set of programs that are actively attempting to document health impacts, most are measuring only a few of the potential outcomes. No single program in our set of 63 is measuring all 23 indicators. On average, the programs in our set are tracking between four and five of these indicators. Out of 63 programs, 10 are tracking 10 or more different indicators. More than half of the programs (37) are tracking 3 indicators or fewer.

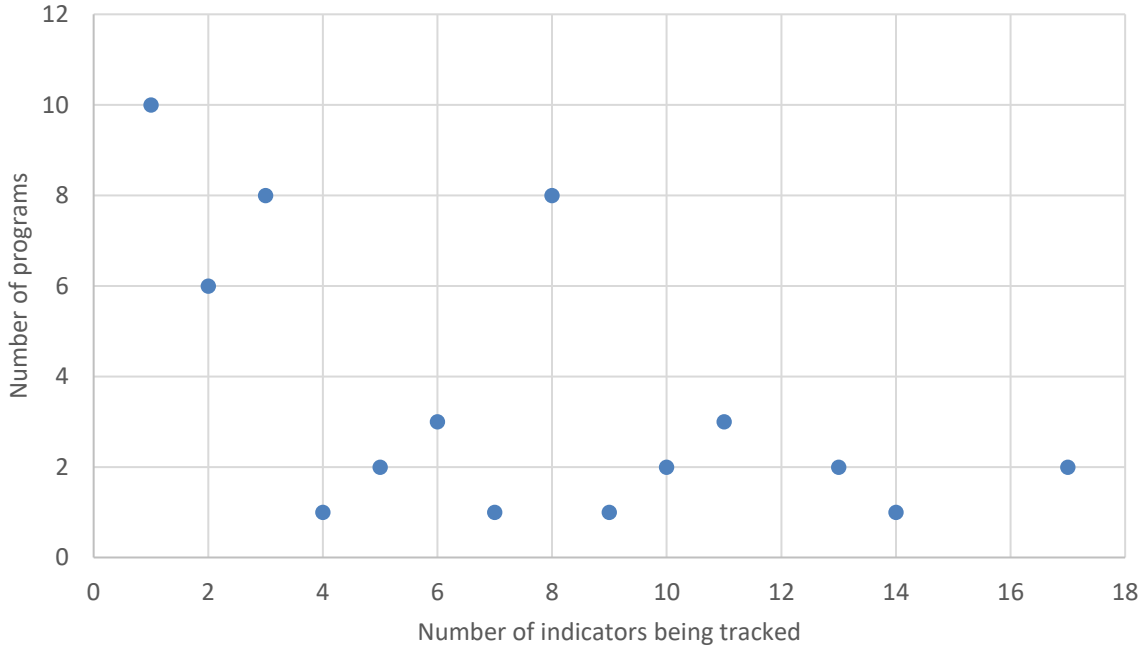

Figure 6. Number of indicators being tracked by programs

Energy Savings as an Indicator of Health

Measurement of energy savings does not provide direct measurement of health impacts but can be a proxy from which health outcomes are inferred. Although a program's energy savings is not a measurement of health outcomes, it can be an effective tool for helping ensure the effectiveness of programs designed to produce more equitable outcomes in communities. For example, energy savings lead to reduced energy bills for program participants, freeing up families to spend money on health care costs, food, and so on. Reducing energy costs can be particularly beneficial to the populations experiencing disproportionately high burdens—low-income and minority families (Drehobl and Ross 2016).

Saving energy can also produce public health benefits from avoided fossil fuel pollution due to the decreased demand on power plants. [16] As discussed earlier in this paper, certain populations are exposed to higher levels of particulate pollution and suffer higher burdens of diseases that are exacerbated by exposure to fossil fuel pollution, such as asthma. Documented energy savings can be used to model air pollution impacts to help ensure that the program is achieving the desired public health benefits through avoided pollution.

[16] For more on this, see the joint report from ACEEE and Physicians for Social Responsibility, *Saving Energy, Saving Lives: The Health Impacts of Avoiding Power Plant Pollution with Energy Efficiency* (Hayes and Kubes 2018).

Human Health and Wellness Indicators

Some programs assess the health and wellness impacts of their activities by directly measuring human health outcomes. This might include tracking the number of times household members visit the emergency department or symptoms related to specific medical conditions such as asthma or COPD. Direct measurements of human health and wellness outcomes are particularly valuable. Compared to other indicators, they provide the clearest measure of a change in an individual's health. This information might come from medical records documenting trips to the doctor or from a survey of the building occupants. Among our programs, the use of medical records was rare.[17] Figure 7 lists the number of times specific human health outcomes were measured in our set of 63 programs. As it shows, asthma symptoms/uncontrolled asthma and comfort are the most commonly measured health outcomes. Trips to the emergency room, respiratory illnesses, days of missed school, and hospital admissions are, respectively, the next most commonly used indicators. Additional indicators used by multiple programs included visits to a doctor, days of missed work, and calls to a doctor. As previously discussed, most programs are tracking fewer than three indicators. The fairly balanced use of the 10 indicators in figure 7 suggests that among programs that are actively attempting to document human health outcomes, no dominant set of human health and wellness indicators is being used.

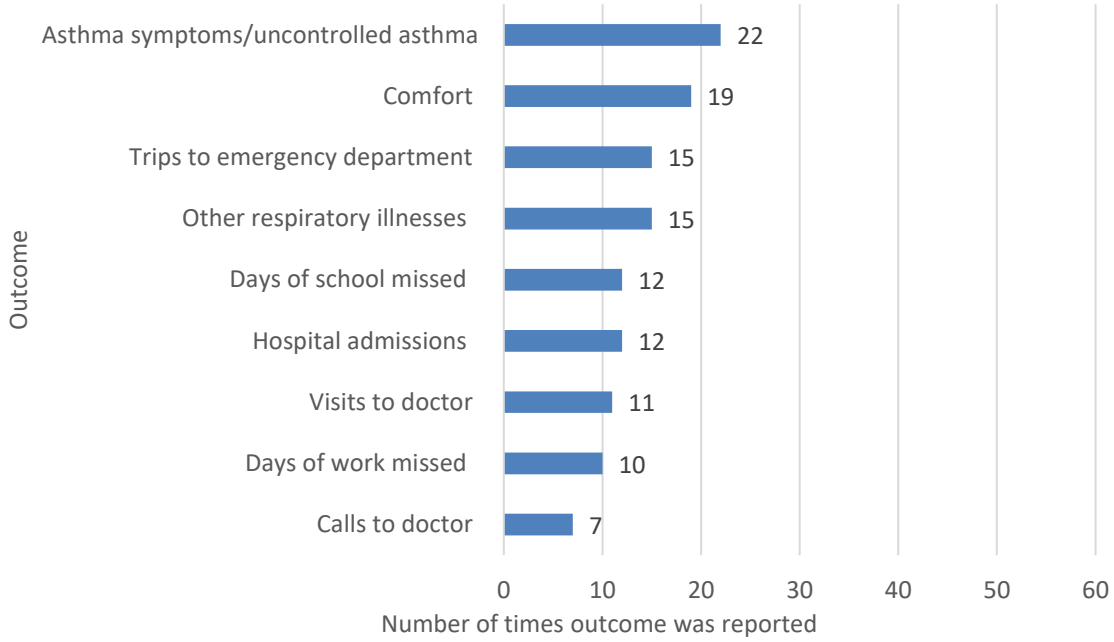

Figure 7. Human health and wellness outcomes measured by programs

[17] Multiple programs reported failed attempts to collect data using medical records due to patient privacy protections.

Indoor Environmental Quality Indicators

The indoor environment can have significant impacts on health. Recognizing this, some programs track indoor environmental quality indicators as a proxy for measuring health outcomes. These indicators include quantitative changes in variables that reveal the healthfulness of a living environment such as particulate matter, carbon dioxide, and VOCs. Programs also assess indoor humidity and temperature. Other measurements include a variety of qualitative assessments such as the presence of triggers for respiratory illness (e.g., pet dander, pests, mold, and so on). The types of environmental measurements we observed in our sample set can be found in figure 8. As indicated, carbon dioxide/ventilation rates were the most commonly measured environmental indicator. This was followed by insects (including cockroaches), rodents, water drippage/condensation/dampness, mold, smoke, particulate matter, and temperature. Humidity, carbon monoxide, VOCs, pet dander, and radon were also measured.

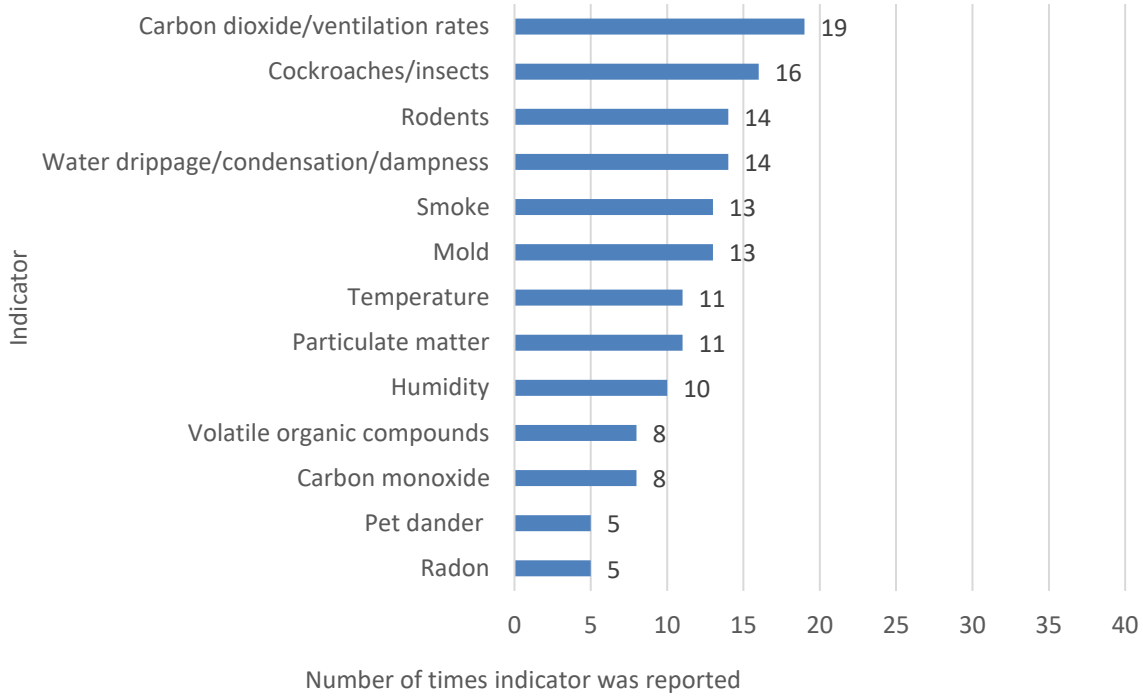

Figure 8. Indoor environmental quality indicators measured by programs

As the figure also shows, even the most commonly measured indicator, carbon dioxide/ventilation rates, was tracked by only 30% of programs (19 of 63). Although all of these programs are documenting health impacts, the types of indicators being measured vary greatly. No single program measured all of the indicators. The Grassroots Green Homes (GGH) program in Pittsburgh, Pennsylvania, is an example of a program that uses environmental measurements to assess health impacts of program interventions. GGH assesses lead, mold, radon, and fine particulate matter (Denson and Hayes 2018). A study conducted in 35 states by Oak Ridge National Laboratory measured levels of carbon monoxide (CO), radon, formaldehyde, temperature, humidity, and moisture (Pigg et al. 2014).

In addition to variability in the specific indicators that programs are tracking, the methods of data collection also vary widely, as discussed in the next section.

SAMPLE PROGRAM APPROACHES

Table 2 summarizes varied approaches for a small selection of programs tracking health outcomes.[18]

Table 2. Approaches to tracking health outcomes

Program name	Health indicators measured	How measured	Results
Bronx Healthy Buildings Program[1]	• Avoidable hospital admissions due to asthma • Avoidable emergency department visits due to asthma • School absenteeism due to asthma	Data overlay from several sources, including patient medical records; housing violations reported to city government; weatherization program assistance recipients	91% reduction in avoidable hospital admissions, 65% reduction in avoidable emergency department visits, 65% reduction in avoidable school absenteeism caused by respiratory illness[2]
Grassroots Green Homes[3]	Radon levels, particulate matter, mold, and lead	Environmental testing; includes pre- and post-intervention surveys to assess behavior change and indoor air quality	Average decrease in radon levels post-intervention, decrease in indoor particulate matter, decrease in presence of mold
Green & Healthy Homes Initiative Asthma Reduction Program[4]	• Uncontrolled juvenile asthma symptoms • Juvenile asthma-related hospitalizations • Juvenile asthma-related emergency room visits • Juvenile asthma-related physician visits • Calls to physicians for juvenile asthma-related emergency room visits • Days of school missed due to asthma	Testing for mold, radon, and asbestos; baseline survey with six-month post-intervention follow-up survey conducted by phone interview with program participants	74% reduction in uncontrolled episodes, 65% reduction in childhood asthma-related hospitalizations, 27% reduction in emergency room visits
Master Home Environmentalist (MHE)[5]	Improvements in asthma or allergies of children	Survey of self-reported health outcomes	Program results not publicly available

[18] This table is illustrative and is intended to provide examples that demonstrate a range of approaches being used by programs. It is not a complete listing of all approaches, and each program or study listed might have additional data that are not described in our table.

Program name	Health indicators measured	How measured	Results
Green multifamily low-income housing[6]	$PM_{2.5}$, formaldehyde, nicotine, nitrogen dioxide, carbon dioxide, and air exchange, mold, pests, inadequate ventilation, and stuffiness	Environmental sampling, home inspections, health questionnaire	47% fewer sick-building-syndrome symptoms
Melrose Commons V, Leadership in Energy and Environmental Design (LEED) certified affordable housing complex[7]	Respiratory symptoms; asthma symptoms disrupting sleep; urgent visits to a health care professional for asthma; days with asthma symptoms, asthma episodes; days of work, school, or day care missed; emergency department visits; knowledge about dust mites, roaches, mold, and chemical irritants; and behavioral changes	Pre- and post-intervention home-based respiratory health questionnaire	Decreases in daily respiratory symptoms, asthma symptoms disrupting sleep in the past month, and urgent visits to a health care professional for asthma in past three months Decrease in days with asthma symptoms, asthma episodes, days of work, school, or day care missed, emergency department visits.

[1] Located in New York City. buildhealthchallenge.org/communities/awardee-bronx-nyc/. [2] These results are extracted from information submitted on nomination forms. The data used to determine these outcomes are not publicly available. [3] Located in Pittsburgh. getenergysmarter.org/community-projects. [4] Located in Baltimore. www.greenandhealthyhomes.org/get-help/find-ghhi-site#baltimore-md. [5] Located in Seattle. www.lung.org/local-content/_content-items/our-initiatives/current-initiatives/mhe-program.html. [6] This information comes from a research study evaluating low-income housing in Massachusetts: www.ncbi.nlm.nih.gov/pubmed/24941256. [7] This information comes from a research study evaluating affordable housing in the South Bronx: www.ncbi.nlm.nih.gov/pubmed/23543019.

Recommendations

START TRACKING AND DOCUMENTING HEALTH OUTCOMES

Energy efficiency programs that are not currently tracking health outcomes can begin by developing a data collection plan. Such a plan might identify important outputs and outcomes, the target audience, and a strategic communication plan. This approach can help program administrators think through the costs and benefits of different options. For example, the target audience for the reporting might value peer-reviewed research with control groups but might be persuaded by only one or two data points. Conversely, a program might be interested in reaching a broad variety of partners to build a community-based coalition, and a range of outcomes self-reported by community members who participated in the program might be most persuasive.

In considering alternatives, cost will also be a factor. Indicators that span multiple collection methods will likely increase costs. For example, a program that uses a survey as its data collection method might produce 10 indicators. The same number might be collected by combining multiple data collection approaches such as a survey, environmental sensors, and medical records. The latter approach produces the same number of indicators but likely

at a higher cost. The ideal data collection method depends on the desired outcomes of the effort, but selecting just one or two data collection methods might minimize costs.

Another important consideration is whether the data collection is intended for one-time use or will be repeated over the duration of a program. Some programs perform periodic evaluations of their impacts. This practice is frequently seen in the context of utility-run programs. Many of the evaluations included in our data set are one-time studies that have never been repeated. When balancing cost and resources, a program implementer might decide that it makes sense to expend more resources or invest in a higher degree of rigor if the program is only going to be evaluated once.

While there are no gold-standard approaches, programs might consider some of the approaches identified in this report, including the following:

- *Conduct a pre-intervention or baseline assessment*. Programs can borrow from existing examples to design a baseline assessment of the home and/or occupant health. See aceee.org/research-report/h1901 for an example of a pre-assessment survey issued through a cooperative effort of federal agencies.
- *Conduct a post-intervention assessment*. As discussed earlier, post-intervention assessments can be conducted by a variety of methods. A low-cost approach for programs not currently collecting this information might include some form of questionnaire or survey that can be provided to participants. Simple surveys can be created or adopted from other programs or agencies. See aceee.org/research-report/h1901 for a post-assessment survey used to evaluate a program run by the Tennessee Valley Authority.
- *Collect multiple indicators that align with program goals*. Our results indicate that most programs are tracking a minimum of 3 separate indicators and that more robust efforts incorporate 10 or more indicators. Identifying a purpose for tracking health outcomes can help determine the best methods and appropriate level of rigor for collecting and handling the data. Goals will need to be considered in the context of resources available to conduct the effort, such as the availability of staff to manage the effort and access to technologies used to evaluate environmental conditions or assess health.
- *Collect indicators that directly measure human health and wellness*. Being able to document actual changes in the health of program participants is one of the clearest ways to demonstrate a program's health impact (in contrast to inferring or predicting health impacts). This approach can be employed at a relatively low cost by making use of existing surveys.

Storytelling

Although storytelling is not one of the methods evaluated in the research for this report, programs that lack the resources to collect and track data on participant health outcomes might consider collecting anecdotal information to document their impacts. Articles or videos detailing specific instances where someone's health was affected by a program can tell a compelling story about the impacts of the program. ACEEE has worked with several programs to produce this type of video, some of which can be viewed here: aceee.org/topics/health-environment.

BUILD COLLABORATIVE CROSS-SECTOR RELATIONSHIPS

Programs operating at the intersection of energy efficiency and health can involve cross-sector partnerships. In the context of trying to build or strengthen processes of tracking and reporting health outcomes, collaborating with an outside organization such as a local health department or medical center can provide the data and expertise to appropriately track and report the health impacts of the implemented measures. For example, health-focused professionals may have access to medical records, bring knowledge helpful to navigating health record privacy protections, refer or identify households that will most benefit from programs, and understand the methods and rigor needed to collect data that are compelling to health insurance providers, hospitals, or other potential program funders. [19]

NeighborWorks of Western Vermont's Health Squad teamed up with a local health care facility, Rutland Regional Medical Center (RRMC), to begin the Healthy Homes Initiative. RRMC is able to access their own electronic medical records (EMRs) to ascertain which patients are frequently visiting the emergency room or being admitted to the hospital for an illness or injury related to their home environment. With their patient record, RRMC staff know the exact reasons and number of times that individual has visited their facility. They then refer that patient to HEAT Squad.

In Oregon, the Community Services Consortium (CSC) and Samaritan Health Network work together. CSC is a community action agency (CAA)[20] that offers several services, including housing, nutrition, education, and employment, to residents in three counties. Samaritan is a coordinated care organization (CCO), which is a network of varied health care providers such as primary care, mental health, and dental providers serving state Medicaid recipients (Samaritan 2018). Together, they offer weatherization services and visits from home health nurses to help assess respiratory wellness, among other things.

SET INDUSTRY STANDARDS

No industry standard of proof or rigor is needed to demonstrate a relationship between a program intervention and a health outcome. Program administrators attempting to navigate the many options will have different goals, and those goals can help dictate the methods of data collection used. One important concern that will likely influence the most appropriate method of data collection is the intended audience. If the data collected will be used to seek reimbursement for costs in the context of a utility-run program, the state body regulating the utility will likely have issued guidance on standards that must be met.[21] Alternatively, if a program is seeking reimbursement from a health insurance provider, health payer, or

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[19] For more information on program models and approaches for developing these cross-sector collaborations, see the Energy-Plus-Health Playbook here: www.veic.org/resource-library/energy-plus-health-playbook (Capps, Curry, and Leven 2019).

[20] CAAs are organizations that work to better focus available local, state, federal, and private resources to assist low-income individuals and families to acquire useful skills and knowledge, to gain access to new opportunities, and to achieve economic self-sufficiency.

[21] A national survey and description of the methods used to calculate health and environmental impacts of energy efficiency programs in the context of state utility cost–benefit tests is available here: aceee.org/topic-brief/he-in-ce-testing (Kubes 2018).

hospital, the appropriate methods for demonstrating a health outcome may include either medical records or self-reported health outcomes and may focus on high-risk patients with higher health care costs. Despite the multiple uses and audiences for these types of data, the development of standard approaches applied across the industry has potential value.

A standard approach, or set of standard approaches, for documenting health outcomes could help lend credibility to the results that programs report by establishing industry-recognized methods. A standardized approach could also assure program administrators and funders that prioritizing investments that improve tracking and reporting of health outcomes will be fruitful. A third potential benefit is that uniformity across programs provides an opportunity to compile a larger pool of comparable data points that could be used to better understand the relationships between specific efficiency measures and the effects those measures have on health.

Conclusion

Energy efficiency programs can be a powerful tool in helping to preventively address a wide range of public health harms, especially for overburdened populations. These programs have largely been operated by energy utility providers, which rarely prioritize health outcomes and function largely siloed from public health institutions. Research increasingly points to the interrelatedness of health and our living circumstances. The Affordable Care Act has prompted a shift in the health care industry to a preventive focus on patient care. The social determinants of health are now widely recognized and increasingly well understood as factors that influence disparities in health. Cross-sector partnerships bridging health care providers, utilities, and community-based home weatherization programs can forge new partnerships to ensure that health benefits accrue for families that need them most. Tracking and documenting the health outcomes of energy-saving programs can help build this bridge.

In addition to positioning programs to take advantage of the opportunities provided by a shifting health care paradigm, tracking health outcomes of a weatherization plus health program can particularly benefit the overburdened populations those programs serve for many other reasons. Tracking health outcomes can produce actionable data that can be used to design and implement programs that serve the unique needs of the communities they serve. For example, if a community seeks to reduce the number of emergency room visits for children experiencing asthma attacks, a program can be designed to identify and mitigate in-home asthma triggers. A referral system can then be established so that health care providers connect patients to that program. Data on health outcomes can also help programs avoid unintended adverse effects, make a program more competitive for limited funding, and attract partners that can help support and expand the program. Energy efficiency programs are operating in every state in the country. In 2017 alone, utilities spent $7.9 billion on energy efficiency programs (Berg et al. 2018). Whether intended or not, these programs affect the health of the families they serve. Proactively designing programs to take advantage of this relationship is a social good. A good way to start is by tracking and documenting the health impacts of these programs.

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Appendix A. Full List of Programs Included in Data Set

Asterisks denote published studies.

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Alaska Native Tribal Health Consortium (ANTHC) Rural Energy Initiative	ANTHC	Alaska	Commercial; municipalities universities, schools, and hospitals (MUSH); single- and multifamily residential	Yes	No	Modeling
Aspen Historical Society: Carriage House Retrofit	Community Office for Resource Efficiency	Colorado	Residential	Yes	Yes	Modeling
ATL EcoDistrict	EcoDistricts	Georgia	MUSH	Unknown	Yes	Modeling
Austin Energy Green Building	Austin Energy	Texas	Commercial; single- and multifamily residential	Yes	Yes	Inspection
Bronx Healthy Buildings Program	Northwest Bronx Community and Clergy Coalition	New York	Multifamily residential	Yes	Yes	Survey, modeling
Community Services Consortium (CSC)	CSC	Oregon	Single- and multifamily residential; manufactured	Yes	Yes	Survey, inspection
Connecticut Green Bank (CGB) Multifamily Housing Program	CGB	Connecticut	Multifamily residential	Yes	Yes	Modeling

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Development and Application of Select Non-Energy Benefits for the EmPOWER Maryland Energy Efficiency Programs*	Maryland Energy Administration	Maryland	Residential	Unknown	Yes	Modeling
Effect of Weatherization Combined with Community Health Worker In-Home Education on Asthma Control*	King County Housing Authority (KCHA), Public Health — Seattle & King County	Washington	Single- and multifamily residential	Yes	Yes	Survey, inspection
Energy Savings Plus Health Program	Des Moines Public Schools	Iowa	MUSH	Yes	Yes	Survey
Energy Upgrade California Home Upgrade in the Southern California Edison/SoCalGas Territory	Southern California Edison, SoCalGas	California	Single- and multifamily residential	Yes	Unknown	Modeling
EnergyFIT Philly	Energy Coordinating Agency (ECA)	Pennsylvania	Single-family residential	Yes	Yes	Modeling, environmental testing
EnergyWise (EW) (Rhode Island)	National Grid	Rhode Island	Single-family residential	Yes	Yes	Modeling
Exploring Potential Impacts of Weatherization and Healthy Homes Interventions on Asthma-related Medicaid Claims and Costs in a Small Cohort in Washington State*	Oak Ridge National Laboratory	Washington	Single-family residential; manufactured	Yes	Yes	Medical records, in-person survey
Grassroots Green Homes	Conservation Consultants Inc. (CCI)	Pennsylvania	Single-family residential	Yes	Yes	Survey, environmental monitoring/testing, modeling

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Green & Healthy Homes Initiative: Improving Health, Economic, and Social Outcomes Through Integrated Housing Intervention*	Green & Healthy Homes Initiative	Maryland	Single- and multifamily residential	Yes	Yes	Survey
Green Assistance Program (GAP)	San Diego Green Building Council	California	MUSH	Yes	Yes	Unknown
Health & Household-Related Benefits Attributable to the Weatherization Assistance Program*	Oak Ridge National Laboratory	National	Residential	Yes	Yes	Survey
Health and Housing Outcomes from Green Renovation of Low-Income Housing in Washington, DC*	Enterprise Community Partners	District of Columbia	Multifamily residential	Yes	Yes	Survey, visual inspection, environmental sampling
Health Benefits of Green Public Housing: Associations with Asthma Morbidity and Building-Related Symptoms*	Boston Housing Authority, Trinity Management Company, Beacon Communities	Massachusetts	Multifamily residential	Yes	Yes	Survey, inspection
Health Outcomes and Green Renovation of Affordable Housing*	Enterprise Green Communities	Minnesota	Multifamily residential	Yes	Yes	Interview

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Health Overlay to the Integrated Physical Needs Assessment (IPNA)	Enterprise Community Partners, Local Initiatives Support Corporation, New York City (NYC) Department of Housing Preservation and Development, NYC Department of Health and Mental Hygiene	New York	Multifamily residential	Yes	Yes	Inspections, performance test-outs
Healthy Home Program (at Children's Mercy Kansas City)	Children's Mercy Kansas City	Missouri	Single- and multifamily residential	Yes	No	None
Healthy Homes Des Moines	Polk County Housing Trust Fund, Polk County Health Department, Mercy Medical Center, Broadlawns Medical Center, UnityPoint Health, the City of Des Moines, Viva East Bank, the Mid-Iowa Health Foundation, EveryStep, Polk County Public Works, Des Moines Public Schools, Telligen Community Initiative, Rebuilding Together	Iowa	Residential	Yes	Yes	Surveys, asthma control tests (pre and post)
Healthy Homes Incentive Program (HHIP)	Grounded Strategies	Pennsylvania	Single-family residential	Yes	Yes	Survey, interview
Healthy Homes Initiative	NeighborWorks of Western Vermont (NWWVT)	Vermont	Single- and multifamily residential	Yes	Yes	Survey, modeling

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Home Energy Solutions - Income Eligible	United Illuminating	Connecticut	Single- and multifamily residential	Yes	Yes	Environmental assessment
Home Performance with ENERGY STAR	New Jersey Board of Public Utilities	New Jersey	Single- and multifamily residential	Yes	Yes	Inspection
Home Works of America and Help My House Pilot Partnership	Home Works of America, Help My House	Georgia, North Carolina, South Carolina	Single-family residential	Yes	Yes	Inspection, modeling
HomeWise	City of Fort Collins	Colorado	Single- and multifamily residential	Yes	Yes	Survey
Impact of LEED-Certified Affordable Housing on Asthma in the South Bronx*	Blue Sea Development Company	New York	Multifamily residential	Yes	Yes	Survey
Indoor Air Quality in 24 California Residences Designed as High-Performance Homes*	Lawrence Berkeley National Laboratory	California	Residential	Yes	Yes	Environmental measurements, inspections, diagnostic testing, surveys
Indoor Air Quality in Green vs. Conventional Multifamily Low-Income Housing*	Department of Environmental Health, Harvard School of Public Health; Boston Housing Authority; Committee for Boston Public Housing	Massachusetts	Multifamily residential	Yes	Yes	Survey, inspection, environmental testing

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Low-Income Multifamily Health- and Safety-Related NEIs Study (TXC 50) Preliminary Findings Report*	Three3, Inc., NMR Group, Inc.	Massachusetts	Multifamily	Yes	Yes	Survey
Mass Save Home Energy Services (HES)	All Massachusetts electric and gas utilities and program administrators	Massachusetts	Single- and multifamily residential	Yes	Yes	Modeling, tracking of measures installed
Master Home Environmentalist (MHE)	American Lung Association in Washington	Washington	Single- and multifamily residential	Yes	Yes	Survey, interviews
Metro Department of General Services' LEED® Building Program; Case Z-Study: Fire Station 19	Metro Nashville Department of General Services	Tennessee	MUSH	Yes	Yes	Modeling, interviews
Moving into Green Healthy Housing*	University of Illinois at Chicago	Illinois	Multifamily residential	Yes	Yes	Survey
National Weatherization Assistance Program Impact Evaluation: Impact of Exhaust-Only Ventilation on Indoor Radon and Humidity – A Field Investigation*	Oak Ridge National Laboratory	National	Single-family residential	Yes	Yes	Measurements
New Jersey Comfort Partners Program	New Jersey Board of Public Utilities	New Jersey	Single- and multifamily residential	Yes	Yes	Modeling, inspection

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
New York State Weatherization Assistance Program (NYSWAP)	New York State Homes and Community Renewal	New York	Group homes/homeless shelters; single- and multifamily residential	Yes	Yes	Modeling
One Touch	Tohn Environmental Strategies	Nebraska, Minnesota, New Hampshire, Massachusetts, Vermont	Residential	Yes	Yes	Unknown
Particulate Matter Concentrations in Residences: An Intervention Study Evaluating Stand-Alone Filters and Air Conditioners*	School of Medicine, University of Michigan; School of Public Health, University of Michigan; School of Environmental Science and Engineering, Donghua University; College of Public Health, University of Iowa; Community Action Against Asthma	Michigan	Single-family residential	Yes	Yes	Environmental measurements
Philadelphia Energy Campaign	Philadelphia City Council	Pennsylvania	Multifamily residential; MUSH	Unknown	Yes	Modeling
Pittsburgh 2030 District	Green Building Alliance	Pennsylvania	MUSH; commercial; industrial	Yes	Yes	Survey, modeling
Putting on AIRS (Asthma Indoor Risk Strategies)	Connecticut State Department of Public Health	Connecticut	Residential	Yes	Yes	Unknown
RENEW Multi-Family	Emerald Cities Collaborative	California, Washington	Multifamily residential	Yes	Yes	Modeling

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Replacing Windows Reduces Childhood Lead Exposure: Results from a State-Funded Program*	University of Illinois at Chicago, Peoria City/County Health Department, National Center for Healthy Housing	Illinois	Residential	Yes	Yes	Survey
Residential Indoor PM2.5 in Wood Stove Homes: Follow-Up of the Libby Changeout Program*	Center for Environmental Health Sciences, Department of Biomedical and Pharmaceutical Sciences, The University of Montana; Department of Mathematical and Computer Sciences, Colorado School of Mines; Environmental and Occupational Health Sciences, University of Washington; Department of Chemistry and Biochemistry, The University of Montana; Lincoln County Environmental Health Department	Montana	Single-family residential	Yes	Yes	Measurements
Rochester Safe and Efficient Homes Initiative (RASHI)	The Community Foundation	New York	Single-family residential	Yes	Yes	Survey, interviews

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Self-Reported Health Outcomes Associated with Green-Renovated Public Housing among Primarily Elderly Residents*	National Center for Healthy Housing; Southwest Minnesota Housing Partnership; University of Minnesota Center for Sustainable Building Research, College of Design	Minnesota	Multifamily residential	Yes	Yes	Interview, inspection, testing
SystemVision	Advanced Energy	North Carolina	Single- and multifamily residential	Yes	Yes	Environmental measurement, modeling
The Breathe-Easy Home: The Impact of Asthma-Friendly Home Construction on Clinical Outcomes and Trigger Exposure*	Faculty of Health Sciences, Simon Fraser University, Burnaby	Washington	Unknown	Yes	Yes	Survey, inspection

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
The Effects of an Energy Efficiency Retrofit on Indoor Air Quality*	Department of Chemistry and Biochemistry, Arizona State University; City of Phoenix Housing Department; Indoor Environment Group, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory; Rinker School of Construction Management, University of Florida; School of Sustainable Engineering and Built Environment, Arizona State University	Arizona	Multifamily residential	Yes	Yes	Survey, measurement/testing
Thermal and Health Outcomes of Energy Efficiency Retrofits of Homes of Older Adults*	Shimberg Center for Housing Studies, University of Florida; Arizona State University; The Elemental Group; City of Phoenix Housing Department	Arizona	Multifamily residential	Yes	Yes	Survey, measurement/testing
Two Shades of Green (TSG)	Local Initiatives Support Corporation (LISC)	New York	Multifamily residential	Yes	Yes	Survey, bill data
Ventilation and Indoor Air Quality in New Homes: California Air Resources Board*	California Energy Commission	California	Single-family residential	Yes	Yes	Measurement/testing

Program name or title of study	Program administrator or research institution	State	Sector	Pre-assessment	Post-assessment	Data collection method
Ventilation, Indoor Air Quality, and Health in Homes Undergoing Weatherization*	University of Illinois at Urbana-Champaign, University of Illinois at Chicago School of Public Health, National Center for Healthy Housing	Illinois	Single-family residential	Yes	Yes	Survey, interview, environmental testing
WarmChoice®	Columbia Gas of Ohio	Ohio	Single- and multifamily residential	Yes	Yes	Modeling
Washington State Weatherization Plus Health Program (Wx+H)	Washington State Department of Commerce	Washington	Residential	Yes	Yes	Surveys, inspections
Watts-to-Wellbeing: Does Residential Energy Conservation Improve Health?*	National Center for Healthy Housing, Tohn Environmental Strategies, CNT Energy, Enterprise Community Partners	Illinois, Massachusetts, New York	Multifamily residential	Yes	Yes	Interview, measurement/testing
Weatherization and Indoor Air Quality: Measured Impacts in Single-Familly Homes under the Weatherization Assistance Program*	Oak Ridge National Laboratory	National	Single-family residential and manufactured	Yes	Yes	Survey, measurement/testing, inspection
Zero Energy Modular (ZEM) Program	Vermont Energy Investment Corporation (VEIC)	Vermont	Single-family residential	No	Yes	Inspections, performance test-outs

*** Pubished study**