Opinion Dynamics

MEMORANDUM

To: Nick Warnecke, Tammy Jackson, Ameren Illinois Company; and Elizabeth Horne, ICC Staff

From: The Opinion Dynamics Evaluation Team

Date: April 4, 2025

Re: Healthier Homes Program Design Review and NEI Research

This memorandum presents findings and results from Opinion Dynamics' program design review for the 2023 Ameren Illinois Company (AIC) Healthier Homes Channel, as well as findings from our exploratory non-energy impact (NEI) research. The objective of the program design review was to develop an understanding of design and implementation best practices, as well as to compile lessons learned from other program administrations. The primary aim of the NEI research was to explore, identify, and document potential NEIs that the channel could generate over time. AIC may use the findings to inform future program improvements and develop evaluation strategies for measuring any NEIs that AIC opts to promote.

INTRODUCTION

The Healthier Homes channel partners with healthcare providers and local community organizations to identify income qualified (IQ) or underserved households with a history of asthma or other respiratory ailments. AIC provides energy efficiency and health and safety services to deliver energy bill savings and preventative care to these households. The offering includes an in-home health and energy assessment; various energy-saving products like LEDs; larger weatherization and HVAC upgrades including air sealing and advanced thermostats; and indoor air quality (IAQ) improvement measures such as moisture control, hypoallergenic bedding, mold remediation, IAQ monitors, and carbon monoxide (CO) detectors. Some measures, such as dehumidifiers and air purifiers, are "hybrid measures" that save energy and improve IAQ. Interviews with program staff and implementation partners revealed a few NEIs anticipated by the program: time savings, fewer doctor visits, and improved IAQ (defined as reduced particulate matter, carbon dioxide, moisture, and humidity). The program measures IAQ and has begun studying preliminary data from IAQ monitors at participating and non-participating homes.

The Healthier Homes channel is based on the US Department of Housing and Urban Development's principles of a healthy home. These principles include keeping homes dry, clean, safe, well-ventilated, pest-free, contaminant-free, well-maintained, and thermally controlled.[1] These guiding principles have served as a blueprint for AIC's Healthier Homes channel and many programs aimed at creating healthier homes across the United States.

Interviews with AIC staff and implementers showed that key staff within the Healthier Homes channel collaborate regularly to navigate project updates and challenges. One project was completed in 2024, while six others were in

[1] US Department of Housing and Urban Development. *Healthy Homes: Eight Tips for Keeping a Healthy Home*. n.d. Archived December 16, 2024. https://web.archive.org/web/20240927064155/https://www.hud.gov/sites/documents/HH8TIPS.PDF.

the documentation phase, meaning the home assessments had been completed but required paperwork was still in the process of being completed. Although there have been minimal deviations from the initial design, the unique needs of individual homes resulted in increased costs and a slower implementation pace. The channel established partnerships with healthcare organizations for client referrals, which staff report has increased service access. However, the program continues to encounter challenges related to project timing, which require efforts to streamline processes. The rising cost of materials has increased expenses, making it challenging to meet original project targets. Currently, contractors are not paid until the project is completed. They have expressed that receiving 20% of the funding upfront could help them source materials more quickly, potentially reducing project completion time by one to two weeks. Furthermore, the availability of contractors who can perform the complex work needed is limited. AIC and implementers have been flexible, allowing for adjustments as needed, and the implementers are currently looking into additional funding sources to alleviate cost-related challenges.

EVALUATION METHODS

PROGRAM DESIGN REVIEW

Opinion Dynamics conducted a program design review of similar initiatives and programs by utilities and non-utilities using a targeted internet search to collect relevant secondary data. To identify relevant programs, we examined websites belonging to utilities, nonprofit organizations, and federal, state, and local governments. We also reviewed residential program evaluations, strategic plans, evaluation plans, and presentations. We focused on active offerings with sources published since 2020, specifically from US states. Upon compiling all relevant sources, we completed a detailed analysis using a structured Excel workbook to identify implementer types, collaborations, program activities, provided measures, target audiences, and any other unique aspects. We summarize the findings and conclusions from this review below and offer recommendations for future program design and delivery.

EXPLORATORY NEI RESEARCH

The evaluation team explored potential NEIs that the Healthier Homes Channel measures could generate. NEIs refer to any additional benefits beyond energy savings such as improved health, fewer missed school days, and many other possible impacts. First, we identified channel measures by reviewing channel materials, quarterly data, and interviews with channel staff and delivery partners. Then, through a collaborative work session with AIC and implementation partners, we identified the highest priority measures for the channel. Finally, we conducted a literature review of the channel's high priority measures to find documentation of NEIs associated with their implementation.

The literature review consisted of systematic online searches for research and evaluation publications with the identified measures. We included peer-reviewed academic papers and presentations, reports from government agencies and non-governmental organizations, and industry evaluations. To find these sources, we searched through residential program evaluation studies, conference proceedings, federal and state websites, manufacturer websites, and reports on relevant state energy efficiency programs. We initially focused on literature published since 2020 from US states with climates similar to Midwestern states. Our initial search yielded few relevant publications for some measures. Consequently, we expanded our review to include literature from the last ten years and included informal articles that mentioned NEIs for measures with limited research findings. We added one book to our source list due to a research team member's familiarity with relevant content in that publication.

To focus our literature search, we created a set of search terms that directed our investigation across different platforms and literature sources. See Table 6 in the Appendix for the specific keywords and phrases we used to identify relevant studies, reports, and evaluations. After finding the relevant literature, we read each source to locate information about possible NEIs, paying particular attention to evidence for the NEIs and the direction or valence of impact (positive, neutral, or negative). Below, we report possible NEIs of individual measures and measure bundles.

PROGRAM DESIGN REVIEW

Through our program design review, we identified 20 comparable, currently active programs and six best practices to guide the implementation of utility-based programs focusing on reducing respiratory issues through home improvements. See Table 5 in the Appendix for the list of programs reviewed. We summarize these best practices in Table 1, while the following section provides more detailed findings.

Although the Healthier Homes Channel is a new offering within AIC's Income Qualified Initiative, it already adheres to the best practices we identified in other established programs, such as focusing on low income households whose members have respiratory issues.

Table 1. Program Design Best Practices

Symbol	Best Practice	AIC Best Practice Alignment
	Focus on low income households in which members have respiratory issues, especially when children are present.	✓
	Collaborate with nonprofit organizations, including community-based organizations.	✓
	Conduct home assessments to identify health hazards and improvement opportunities.	✓
	Provide home upgrades in response to home assessment findings.	✓
	Offer direct education to enhance residents' knowledge of maintaining a safe and healthy home.	✓
	Prioritize eliminating or remediating health hazards such as mold and lead.	✓

PROGRAM DESIGN REVIEW FINDINGS

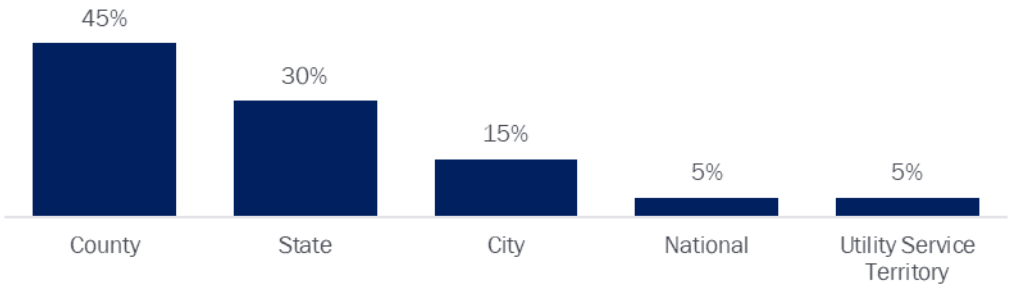
Programs with similar designs or offerings were most commonly provided by the government (11 implementers), followed by nonprofit organizations (8 implementers) and one utility (Table 2).

Table 2. Implementer Type for Programs Reviewed

Implementer Type	Number of Implementers
Government	11
Nonprofit	8
Utility	1
Total	**20**

Programs covered different geographic areas. Most programs operated at the county level (45%), followed by the state (30%) and city level (15%) (Figure 1). Only one program operated nationally, and one covered utility service territory.

Figure 1. Geographic Scope of Programs Reviewed (n=20)



The majority (85%) of reviewed programs generated or anticipated generating NEIs related to health, and over half (60%) reported the same for reduced illness. Additionally, half (50%) reported safety improvements, and nearly half (45%) reported reduced asthma triggers. Safe drinking water and reduced crime, anxiety, and missed school or workdays were the least commonly generated NEIs, only reported for one (5%) program in each case (Table 3).

Table 3. NEIs Generated for Programs Reviewed (n=20)

NEIs Generated	Number of Programs	Percentage of Programs
Health	17	85%
Reduced Illness (e.g., Asthma, Carbon Monoxide or Lead Poisoning)	12	60%
Safety	10	50%
Reduced Asthma Triggers	9	45%
Reduced Injury	8	40%
Improved IAQ	7	35%
Lower Energy Bills	4	20%
Lower Healthcare Costs	4	20%
Enhanced Quality of Life	2	10%
Increased Value of Home	2	10%
Improved Housing Conditions	2	10%

NEIs Generated	Number of Programs	Percentage of Programs
Comfort	2	10%
Safe Drinking Water	1	5%
Reduced Crime	1	5%
Reduced Anxiety	1	5%
Reduced Missed School/Workdays	1	5%

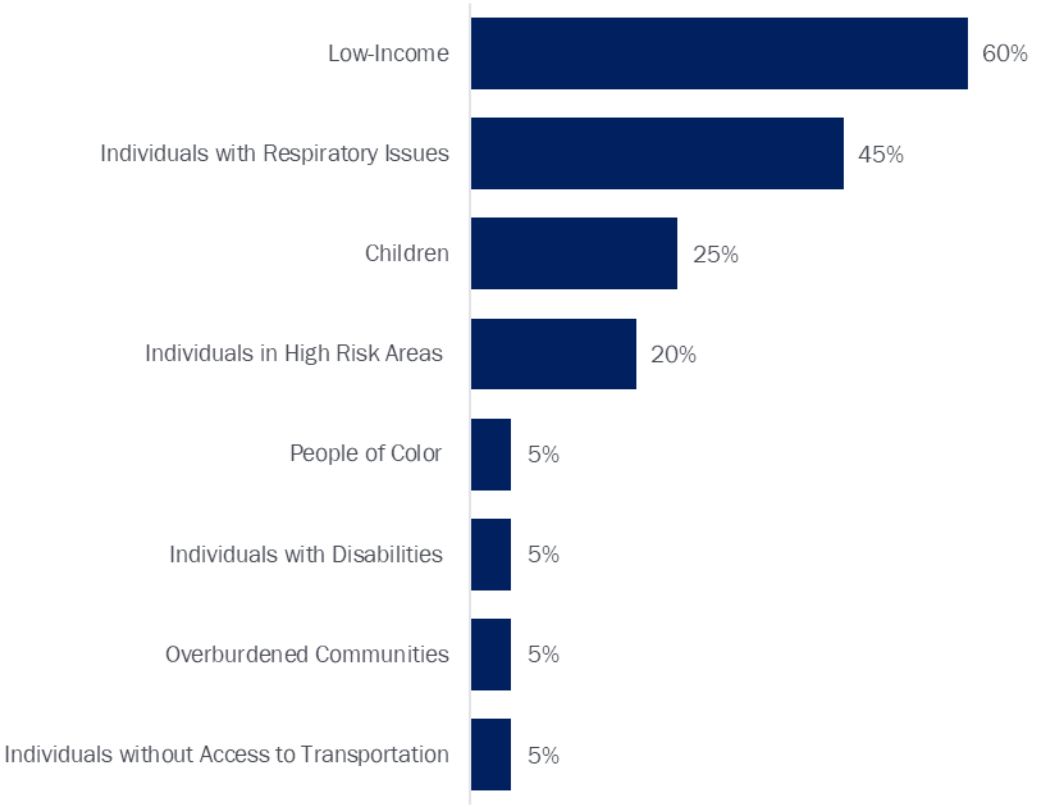
Two of the programs reviewed had engaged in formal evaluations of the NEIs they produced. The Healthy Neighborhoods Program, administered by the New York State Department of Health, conducted an assessment confirming the program's positive NEIs, which included enhancements in health, comfort, air quality, reductions in injuries and illnesses, fewer asthma triggers, and improved housing conditions.[2] Similarly, Efficiency Vermont's Healthy Homes Pilot programs performed a formal assessment that concluded the programs generated NEIs related to health, comfort, reduced injury and illness, reduced asthma triggers, and lower healthcare costs resulting from reductions in medical attention needed from injury or other preventable illnesses related to health hazards in the home.[3]

Programs catered to various target audiences, some with specific eligibility requirements (Figure 2). The most common eligibility requirement for program participants was income qualification (low income), which accounted for over half of the target audience (60%). Individuals with respiratory issues made up the second largest target audience, comprising just under half (45%). Children made up a quarter (25%) of the program's target audience. Some programs served overlapping audiences. For example, a fifth (20%) of programs targeting individuals with respiratory issues also focused on low income individuals. Our analysis suggests a program best practice is to customize to meet the specific needs of target audiences in the communities served.

[2] Reddy, Amanda L., Marta Gomez, and Sherry L. Dixon. "The New York State Healthy Neighborhoods Program: Findings from an Evaluation of a Large-Scale, Multisite, State-Funded Healthy Homes Program." US Department of Housing and Urban Development. April 2017. Accessed March 21, 2025. https://www.asthmacommunitynetwork.org/sites/default/files/resource_files/The_New_York_State_Healthy_Neighborhoods_Program__.22.pdf.

[3] Capps, Laura. *Healthy Homes Vermont 2021.* Efficiency Vermont. April 2022. Accessed March 21, 2025. https://www.efficiencyvermont.com/Media/Default/docs/white-papers/Healthy_Homes_Vermont_2021.pdf.

Figure 2. Target Audiences for Programs Reviewed (n=20)



Collaboration across programs and stakeholders was common and may be used as a best practice to optimize resource allocation, broaden outreach, enhance knowledge sharing, and ensure comprehensive assessments and home upgrades (Figure 3). By partnering with various stakeholders, programs could improve their efficiency and reach and tailor interventions to the unique needs of the communities they serve. Working with partners from diverse sectors also allowed programs to tap into an extensive pool of expertise, resources, and networks, maintaining a high standard of service delivery. Of the programs reviewed, collaboration with nonprofit organizations was the most common (58%), followed by local health departments (42%) and local government (42%). Please note that several of the programs included in the review did not have information about collaborations in their public materials; we were unable to confirm if they did or did have such partnerships.

Working with nonprofit organizations was the most common partnership when implementing programs focused on creating healthier homes. Collaborating with nonprofit organizations could help programs reach people within target communities because many nonprofit organizations seek to foster closer relationships with the communities they serve. Additionally, local health departments could offer insights into what constitutes a healthier home, and local governments could provide assistance in funding and outreach efforts.

Figure 3. Type of Collaborations for Programs Reviewed (n=12)

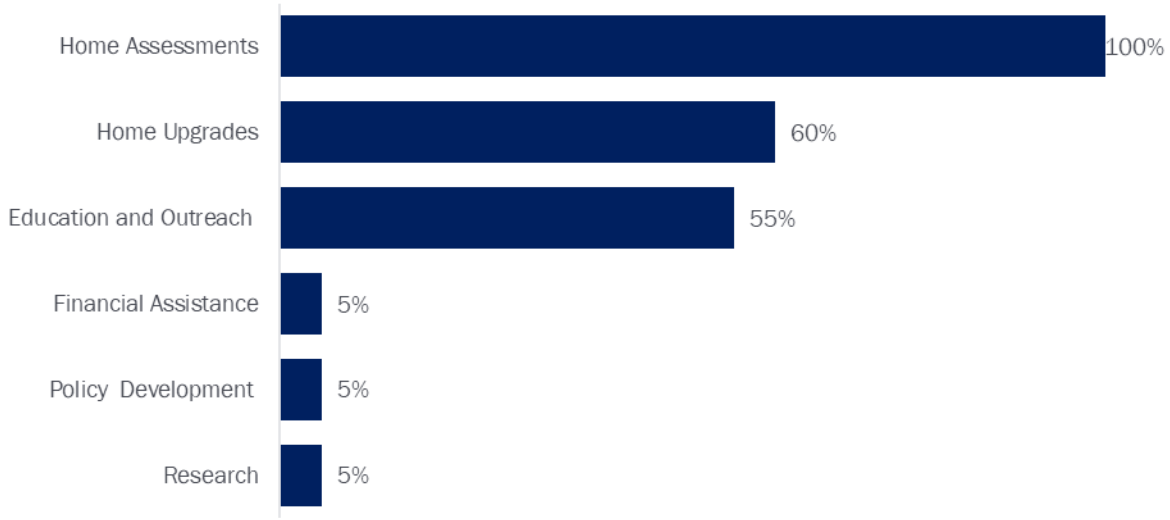
Notes: The sum of percentages exceeds 100% because multiple options were possible for each program. Eight of the programs (40%) reviewed did not have publicly available information on collaboration.

The programs reviewed engaged in a variety of activities (Figure 4). All 20 programs included a home assessment. This typically involved walking through the home to identify health hazards like lead or mold, determining what specific measures the household needs (e.g., smoke or carbon monoxide detectors or air quality monitors), and identifying whole-home upgrade opportunities, such as weatherstripping or equipment upgrades, if the program offers them.

More than half (60%) of the programs offered extensive home upgrades, including equipment upgrades, insulation, air sealing, and carpet or flooring replacement. The programs that lacked the resources or budget to perform home upgrades referred customers to other organizations providing home upgrades at free or discounted rates. Additionally, over half (55%) provided some form of household education, such as informational materials left behind or direct education from the contractor conducting the home assessment.

Our analysis suggests a trifecta of program activity best practices: conducting home assessments to make appropriate recommendations to enhance home health and safety, implementing whole-home upgrades, and providing direct education to improve residents' understanding of home safety and maintenance. Even when programs could not provide whole-home upgrades, establishing partnerships for referrals was a tactic to ensure customers still received the support they needed. These three activity best practices helped address immediate safety concerns and contribute to long-term home improvement and resident empowerment.

Figure 4. Program Activities for Programs Reviewed (n=20)

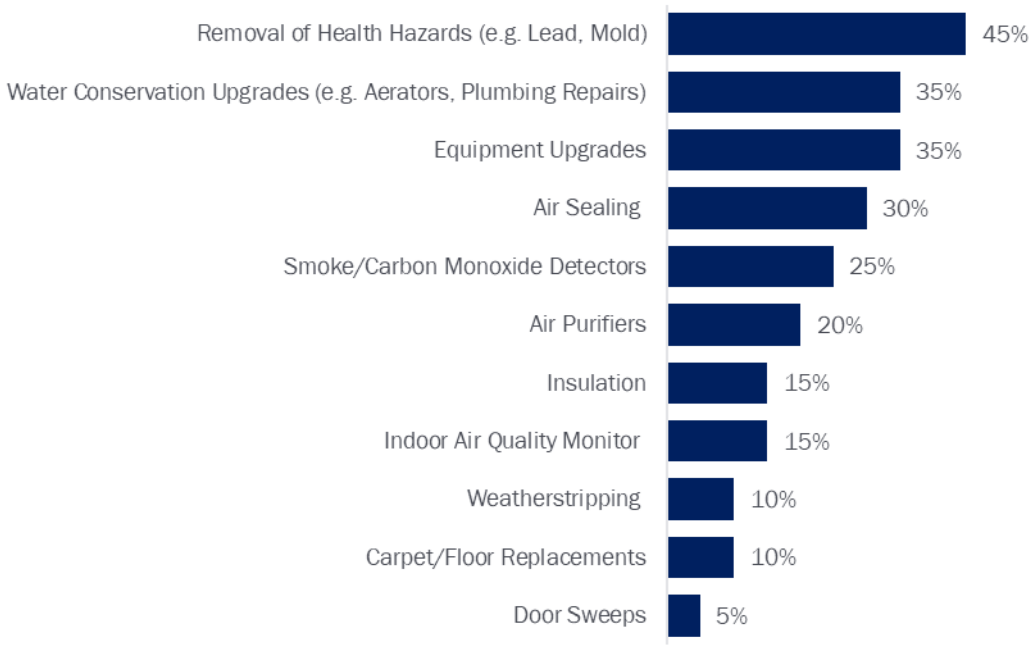


Finally, the reviewed programs provided specific measures, which we grouped into common types (Figure 5). The most common measure type focused on eliminating health hazards (e.g., lead and mold) that contribute to health issues such as asthma. Almost half (45%) of programs performed health hazard elimination, and just over a third (35%) provided water conservation measures, such as plumbing repairs[4] or faucet aerators, to alleviate mold resulting from leaks. About one-third (35%) also carried out equipment upgrades. This included heating and cooling systems, water heaters, stoves, ventilation fans, lighting, fridge and freezers, washing machines, and dehumidifiers. Other measure offerings included air sealing (30%), smoke/carbon monoxide detectors (25%), and air purifiers (20%). Less than a sixth (15%) mentioned providing air quality monitors for their participants.

Unsurprisingly, our analysis confirmed that removing health hazards is a best practice for programs aiming to improve IAQ and alleviate long-term health problems like asthma. Additionally, incorporating water conservation measures and equipment upgrades could further mitigate health risks. Although most programs did not provide IAQ monitors, the three programs that included them in program offerings could benefit residents by allowing them to identify and mitigate harmful pollutants in their living spaces, ultimately leading to improved health outcomes. These devices may empower individuals by giving them the tools and information needed to take proactive steps toward maintaining a healthy indoor environment.

[4] Plumbing repairs are categorized in the water conservation group because programs either mention leak repairs or plumbing repairs generally, but always with a focus on reducing moisture in the home.

Figure 5. Measure Types for Programs Reviewed (n=20)



EXPLORATORY NEI RESEARCH

FINDINGS

For the purposes of this review, we defined NEIs as non-energy impacts on measure users/program participants in single family homes. Based on our NEI literature review, 9 of the 10 Healthier Homes measures included in our review had positive NEIs, and 5 had neutral impacts. We found no research in support of NEIs for one measure; our review was inconclusive for that measure. Furthermore, we examined studies of the Healthier Homes measures in combination with other measures (e.g., air sealing with rim joist insulation). Scrutinizing research findings about these combined measure packages revealed six that continued to have positive NEIs, three had neutral impacts, and one had negative impacts. We deemed an impact neutral when a positive outcome was small enough to be unnoticeable to home occupants or when positive impacts were contingent on specific circumstances and thus not guaranteed. Table 4 summarizes these findings. The following sections organize the Healthier Homes measures into two categories: measures that directly improve IAQ and measures that reduce moisture and mold (and, therefore, indirectly influence IAQ).

Table 4. Valence of Measures in the Healthier Homes Channel

Measure	Positive NEIs	Neutral NEIs	Negative NEIs
Direct IAQ Improvement Measures			
Air Purifiers	✓	✓	
Air Purifiers with Other Measures	✓		
Air Sealing	✓	✓	
Air Sealing with Other Measures	✓	✓	✓

Measure	Positive NEIs	Neutral NEIs	Negative NEIs
Energy Recover Ventilators (ERVs)	✓		
ERVs with Other Measures	✓	✓	
Kitchen Fans	✓	✓	
Moisture and Mold Reduction Measures			
Carpet Removal	✓	✓	
Carpet Removal with Other Measures	✓		
Dehumidifiers	✓		
Dehumidifiers with Other Measures	✓		
Horizontal Guttering and Water Management with Other Measures	✓		
Mold Remediation with Other Measures	✓	✓	
Rim Joist Insulation	✓		
Vapor Barriers	Inconclusive		

This literature review has some important limitations. First, it was meant to introduce the evidentiary basis for NEIs of the Healthier Homes measures rather than serve as an exhaustive exploration. Our search terms were specific and tailored to sources relevant to utility programs. We did not seek out medical research or search medical/health-focused databases. However, given the health-related NEIs we documented, we suspect including such sources would yield additional useful information. Also, the studies we located—often other literature reviews—had inconsistent levels of detail and various definitions for NEIs; for instance, some studies cited improved "health" as an NEI while others specified outcomes like "decreased hospitalizations for bronchitis." In addition, some of the measures' names and relevant terminology overlapped significantly with irrelevant studies. For example, we found very little research about horizontal guttering and water management; adding search terms like "water intrusion," "moisture," "dampness," and "water issues" in homes would have yielded far more studies, but also many more irrelevant ones. We did not formally assess the relative rigor of the studies, but we flagged information coming from industry market actors. We also sought to focus on recent research from the last five years and only include studies based on climates similar to Illinois. After finding too few studies for some measures, we relaxed these criteria to include studies from the last decade. We also included one study from the southeastern US.

DIRECT IAQ IMPROVEMENT MEASURES

"Whole-building air exchange is an important element in maintaining healthy indoor air quality (IAQ) in residential buildings…Other components of a comprehensive IAQ strategy include limiting materials and activities that are a source of pollutants, and employing local exhaust in bathrooms and kitchens where intermittent odors and high concentrations of contaminants are likely to occur."[5]

[5] US Department of Energy (DOE). "Ventilation and Indoor Air Quality in Recently Constructed US Homes." 2024. Accessed December 5, 2024. https://www.energy.gov/eere/buildings/ventilation-and-indoor-air-quality-recently-constructed-us-homes-measured-data.

AIR PURIFIERS

Air purifiers improved IAQ, including benefits such as reduced particulate matter and volatile organic compounds (VOCs). However, few studies demonstrated noticeable health benefits stemming from such air purification, although one cited neutral effects on users.

Air purifiers, also known as air filters or air cleaners, reduce or eliminate pollutants while circulating clean air throughout homes. These are distinct from electronic air cleaners such as ionizers and other ozone-generating air cleaners, which may generate enough ozone to cause damaging health effects and should not be used while people are present.[6]

The 2016 *Home Rx: Health Benefits of Home Performance* literature review studied the effects of in-room air cleaners using filtration rather than ionization, utilizing five relevant studies in its analysis.[7] All five studies found air cleaners improved IAQ, including reduced particulate matter, VOCs, and nitrous oxide. Additionally, one study reported reduced healthcare utilization, and two showed improved lower respiratory health. A 2020 randomized intervention with 32 healthy participants found that while air purifiers contributed to a slight improvement in air quality, they did not significantly impact the overall health.[8] Similarly, the U.S. Environmental Protection Agency (EPA)'s 2018 *Guide to Air Cleaners in the Home* reported that although air purifiers showed slight improvements in respiratory health, they were not always noticeable to impacted individuals because they were typically very small.[9]

We located a single study with NEIs for air purifiers in combination with other measures. The *Achieving Health and Social Equity Through Housing* literature review included this study, which examined air cleaners and cockroach allergen remediation.[10] The study reported that a measure package with high-efficiency air cleaning, education, cockroach extermination, and mattress and pillow encasings reduced cockroach allergen levels by 51%.

The relatively small impacts of air purifiers suggest the need for a comprehensive approach when using them for health benefits. The EPA emphasized that complementing air purifiers with additional measures—such as addressing the sources of indoor pollutants—is essential for achieving optimal air quality because air purifiers filter the air rather than removing pollutants from the environment.[11] According to the EPA, eliminating the sources of pollution, opening windows, and maintaining HVAC systems meaningfully enhanced the effectiveness of air purifiers.

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[6] UMass Amherst. *Fact Sheet for Air Purifiers.* n.d. Archived June 12, 2024. https://web.archive.org/web/20230927002630/https://ehs.umass.edu/sites/default/files/Air%20Purifiers%20122221.pdf.

[7] Wilson, Jonathan et al. *Home Rx: The Health Benefits of Home Performance A Review of the Current Evidence.* Washington, DC: US Department of Energy, 2016. https://www.energy.gov/eere/buildings/articles/home-rx-health-benefits-home-performance-review-current-evidence.

[8] Yoda Yoshiko et al. "Effects of the Use of Air Purifier on Indoor Environment and Respiratory System among Healthy Adults." *International Journal of Environmental Research and Public Health* (2020):17. https://doi.org/10.3390/ijerph17103687.

[9] Environmental Protection Agency (EPA). *Guide to Air Cleaners in the Home.* 2018. Accessed December 9, 2024. https://www.epa.gov/sites/default/files/2018-07/documents/guide_to_air_cleaners_in_the_home_2nd_edition.pdf.

[10] Norton, Ruth Ann et al. *Achieving Health and Social Equity through Housing: Understanding the Impact of Non Energy Benefits in the United States.* Green and Healthy Homes Initiative. 2018. https://www.greenandhealthyhomes.org/wp-content/uploads/AchievingHealthSocialEquity_final-lo.pdf.

[11] UMass Amherst. *Fact Sheet for Air Purifiers.*

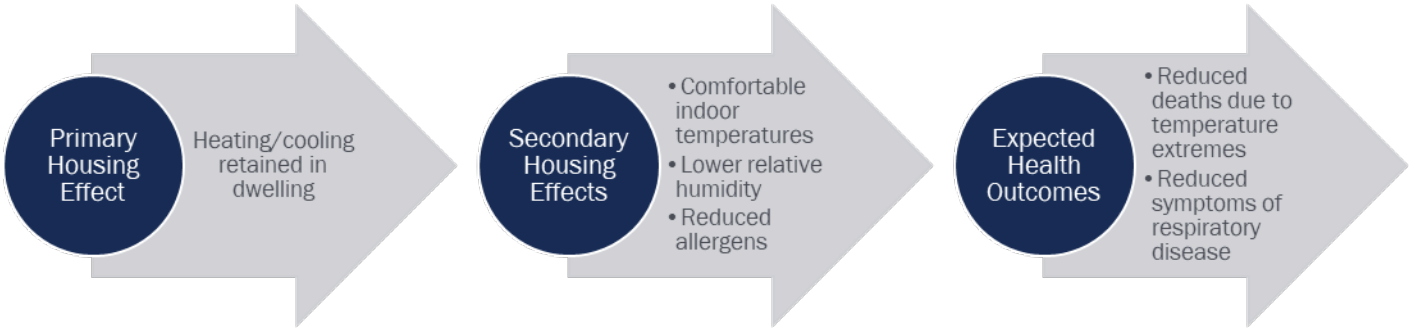
	When installing air purifiers, position them strategically in the most frequently used areas of the home, such as living rooms and bedrooms. Ensure the purifiers are placed away from walls and obstacles for optimal airflow and efficiency. Additionally, ensure customers are educated about the importance of conducting regular maintenance on their HVAC systems and keeping windows open when outdoor air quality is acceptable to enhance overall ventilation.[12] This approach will help maximize the benefits of the air purifiers and improve IAQ effectively.

AIR SEALING

Air sealing alone provided several positive NEIs and one neutral impact. However, air sealing was most often bundled with other measures, such as weatherization packages, that garnered many positive impacts, a few neutral impacts, and two negative impacts.

The research we uncovered suggested several positive NEIs for air sealing itself. The 2016 *Home R_x* literature review included "pathways" for energy efficiency measures to improve occupant health and well-being.[13] The pathways, first created by the International Energy Agency (IEA) in 2014, were a framework to guide the *Home R_x* literature review and were themselves based on research findings. As shown below (Figure 6), NEIs resulting from air sealing include retained heating/cooling, comfort temperatures, and more.

Figure 6. US DOE/IEA Pathway for Health and Well-Being Impacts of Air Sealing



Other studies showed that air sealing protects homes from condensation, preventing mold, rot, and odor problems.[14] It also prevents outdoor air pollutants, pests, and dust from entering homes and is likely to contribute to home comfort.[15] Furthermore, air sealing minimizes external noise by addressing gaps and cracks in doors,

[12] UMass Amherst. *Fact Sheet for Air Purifiers.*

[13] Wilson et al., *Home R_x*

[14] US Department of Energy (DOE) Building Technologies Program. *Building America Top Innovations Hall of Fame Profile: Basement Insulation Systems.* US DOE. January 2013. https://www.energy.gov/eere/buildings/articles/basement-insulation-systems-building-america-top-innovation.

[15] Tonn, Bruce, Eric Rose, Beth Hawkins, and Brian Conlon. *Health and Household-Related Benefits Attributable to the Weatherization Assistance Program*. Oak Ridge National Laboratory. September 2014. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_345.pdf.

windows, and walls, enhancing homes' tranquility and overall comfort.[16] Finally, a 2021 literature review and NEI estimate study for California IOUs associated air sealing with reduced utility shutoffs (due to lower bills/increased ability to pay bills) and better health, safety, and comfort.[17]

However, a 2021 literature review on NEIs for weatherization noted that air sealing impacts are contingent on specific installation circumstances.

> There is "inherent tension existing between reducing air exchange rates in order to save energy and providing adequate air exchange to preserve health…and the complex interplay among air-sealing, mechanical ventilation, levels of indoor and outdoor pollutants, and occupant characteristics that determine respiratory health impacts."[18]

An evaluation of the national Weatherization Assistance Program (WAP) found mixed effects on radon levels in homes since general air sealing tightened homes, which reduced natural ventilation and thus potentially increased home radon levels.[19] And yet, below-grade air sealing, or air sealing that decreased air movement from foundation spaces to living spaces, could reduce radon in occupied spaces. It is because of these nuances that we noted air sealing's possible neutral impact in Table 4.

Air sealing also had NEIs when effectively combined with other measures. An evaluation of NEIs from a low income utility program in the northeast showed that this combination reduced program participants' total annual energy bills by an average of $33.[20] A 2023 evaluation of New Jersey Natural Gas' (NJNG) Home Performance with ENERGY STAR® program revealed NEIs for air sealing in combination with duct sealing, insulation, high-efficiency heating and air conditioning, and water heating.[21] Surveyed program participants reported increased comfort, improved air quality, and reduced noise.[22]

The 2016 *Home R_x* literature review reported many NEIs for air sealing combined with several other measures.[23] The study grouped measures into different bundles. The first bundle, called base energy efficiency, included air sealing, insulation, and heating improvements. This bundle had several positive health-related effects: reduced healthcare utilization, mold, musty smells, and pests; and increased general health/wellness, lower respiratory health (including asthma), upper respiratory health (including colds, flu, nasal allergies, and sinus infections), and heart disease and hypertension. The review included one study finding negative effects of these measures: increased radon and formaldehyde in homes' air, which may have become an issue due to insufficient mechanical

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[16] NMR Group, Inc. X1942C *Cross-Cutting NEI Study—HES and HES-IE NEIs.* 2023. Accessed October 25, 2024. https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fenergizect.com%2Fsites%2Fdefault%2Ffiles%2Fbulk-media%2FCT_X1942C_HES_HESIE_NEIs_FINAL_DRAFT_12MAY2023_redline.docx&wdOrigin=BROWSELINK.

[17] California Investor-Owned Utilities. *California Energy Savings Assistance Program Non-Energy Benefits Final Report*. Prepared by APPRISE. January 2021. https://www.appriseinc.org/wp-content/uploads/2021/01/California-Energy-Savings-Assistance-Program-Non-Energy-Benefits-Final-Report.pdf.

[18] Pigg, Scott et al. *Addressing Non-Energy Impacts of Weatherization*. Oak Ridge National Laboratory. March 2021. https://weatherization.ornl.gov/wp-content/uploads/2021/03/ORNL_SPR-2020_1840.pdf.

[19] Pigg, Scott et al. *Weatherization and Indoor Air Quality: Measured Impacts in Single-Family Homes under the Weatherization Assistance Program*. Oak Ridge National Laboratory. September 2014. https://info.ornl.gov/sites/publications/files/Pub49468.pdf.

[20] Berger, Jacqueline et al. *Estimation of Non-Energy Impacts from Energy Efficiency*. Conference presentation at 2022 ACEEE Summer Study. https://www.appriseinc.org/wp-content/uploads/2022/08/Estimation-of-Non-Energy-Impacts-from-Energy-Efficiency.pdf.

[21] The ENERGY STAR® name and mark are registered trademarks owned by the US EPA.

[22] New Jersey Natural Gas (NJNG). *NJNG Home Performance with ENERGY STAR Process and Impact Evaluation PY1 Final Report.* January 2023. https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.njcleanenergy.com%2Ffiles%2Ffile%2FUTILITY%2520REPORTING%2FNJNG%2FFinal%2520NJNG%2520HPwES%2520PY1%2520Process%2520and%2520Impact%2520Evaluation%2520Report.docx&wdOrigin=BROWSELINK.

[23] Wilson et al. *Home R_x*

ventilation after the measures were installed. Finally, one study in the review found neutral effects on lower respiratory health/asthma.

The second bundle of *Home R_x* measures, called enhanced energy efficiency, included the base energy efficiency measures plus window/door replacement, ventilation enhancement, and a variety of "additional services" to improve the indoor environment, including removing carpets, mold removal, dehumidification, water leak repairs, and more. These enhanced energy efficiency measures again found mostly positive effects: reduced healthcare utilization, mold, water damage, and dust mite allergens; and improved general health/wellness, lower respiratory health/asthma, upper respiratory health, "other" health (blood pressure, fatigue, irritability), comfort, and levels of carbon dioxide, total VOCs, formaldehyde, radon, and airborne mold. One study found negative impacts of increased carbon dioxide, VOCs, particulate matter, and acetaldehyde, as well as contradictory effects on nitrous oxide and formaldehyde levels (which we classified as a neutral NEI).

Another stream of NEI findings associated with air sealing was weatherization programs. Though we did not search for weatherization programs specifically, a few weatherization evaluations that mentioned air sealing as an included measure came up in our search. The national WAP included air sealing as one of its main measures. The program's 2014 evaluation of NEIs featured pre/post and comparison group surveys to gauge changes in NEIs.[24] The study found many statistically significant NEIs. The weatherization package significantly reduced the following:

- Unsafe or unhealthy home temperatures
- Residents needing medical attention because the home became too hot
- Drafts
- Outdoor noise
- Insect infestation
- Mouse infestation
- Mildew odor or musty smells
- Standing water in the home
- Mold in the home
- Headaches
- Persistent cold symptoms
- Visits to emergency rooms for asthma
- Number of days of poor physical health
- Poor mental health
- Not getting enough sleep or rest
- Number of days kept from usual activities

Post-weatherization, participants also reported less financial strain, such as struggling to pay energy bills, being unable to afford prescription medicines, and not purchasing food in order to pay energy bills.

Finally, Xcel Energy's low income weatherization programs also included air sealing as a measure, along with insulation and heating system replacements.[25] A 2020 analysis of Xcel Energy's programs illustrated several NEIs for program participants: reduced asthma, heat stress, cold stress, missed days of work, predatory loans, fire risk, carbon monoxide poisoning, and utility disconnects, as well as increased food security.

[24] Tonn et al., *Health and Household Benefits Attributable to WAP.*

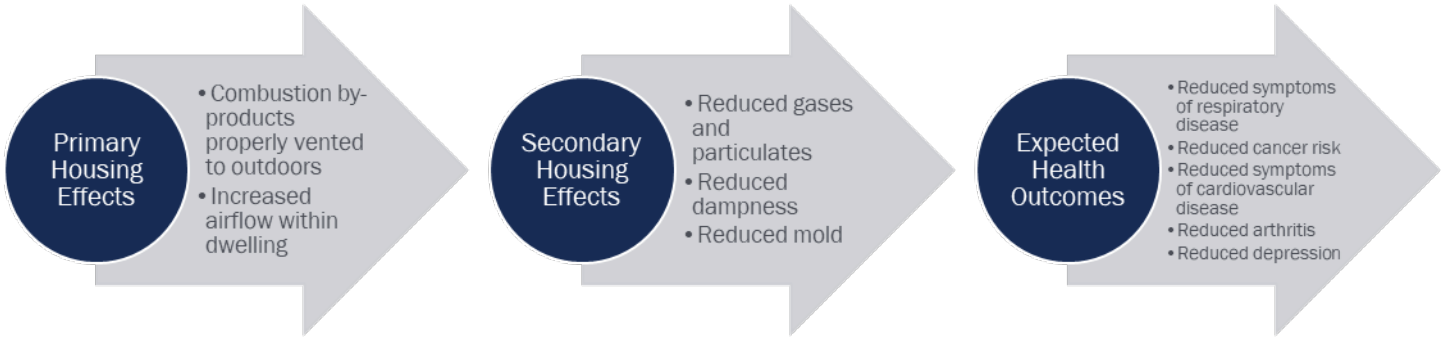
[25] Xcel Energy. *Non-Energy Impact (NEI) Analysis for Xcel Energy's Low-Income Programs.* Prepared by Three[3]. June 26, 2020. https://www.threecubed.org/uploads/2/9/1/9/29191267/non-energy_impacts__nei__analysis_for_xcel_energys_low-income_programs.pdf.

ENERGY RECOVERY VENTILATORS (ERVS)

ERVs improved IAQ, reduced excessively dry indoor environments, and improved comfort. In combination with other measures, they improved comfort and reduced carbon dioxide, acetaldehyde, VOCs, and particulate counts but had neutral impacts on formaldehyde and nitrous dioxide levels.

ERVs connect to the HVAC system, transferring heat and moisture between indoor and outdoor environments. A study comparing ERVs and Heat Recovery Ventilators (HRVs) in Alaska examined the roles they each played in enhancing IAQ, particularly in newer buildings with tight envelopes.[26] Unlike older structures, which often experience air leakage and thus have ongoing air exchange, newer buildings can suffer from insufficient fresh air intake, leading to the accumulation of indoor air pollutants that can adversely affect air quality. Traditional ventilation systems typically exchange indoor air with outdoor air, which can remove moisture without replenishing it during cold weather, resulting in uncomfortably dry indoor environments during winter. The study found ERVs efficiently balanced heat and moisture by transferring energy from the exhaust air to the incoming air stream, improving IAQ while mitigating excessive dryness and fostering a more comfortable living space. A 2024 study conducted in Chicago examined the IAQ of 40 homes before and after installing an ERV.[27] The homes had reduced contaminants associated with various pollutants after installing the ERV, indicating improved IAQ. Finally, the *Home Rx* literature review included a pathway for improved ventilation to ultimately improve occupant health and well-being updated from the IEA's prior research review (Figure 7). This pathway applied to exhaust systems, HRVs, and ERVs.

Figure 7. US DOE/IEA Pathway for Health and Well-Being Impacts of Improved Ventilation



The *Home Rx* literature review also included one study with ERVs as part of an enhanced energy efficiency measure bundle with air sealing, insulation, heating improvements, window/door replacement, a fan, carbon monoxide alarms, a stand-alone HEPA filter, and mold removal.[28] This comprehensive measure package improved comfort and reduced carbon dioxide, acetaldehyde, VOCs, and particulate counts. However, the impacts on formaldehyde and nitrous dioxide were mixed, which indicated a neutral NEI.

[26] Cold Climate Housing Research Center. *Energy Recovery Ventilators in Cold Climates*. n.d. Accessed December 9, 2024. https://cchrc.org/wp-content/uploads/media/ERVs_ColdClimates.pdf.

[27] Kang, Insung et al. "Indoor Air Quality Impacts of Residential Mechanical Ventilation System Retrofits in Existing Homes in Chicago, IL." *Science of the Total Environment,"* 804, (2022), https://doi.org/10.1016/j.scitotenv.2021.150129.

[28] Wilson et al. *Home Rx*.

KITCHEN FANS[29]

Research on kitchen fans supported their role in increased IAQ, including decreased particles, carbon dioxide, radon, and other compounds. However, IAQ impacts were neutral if the fan was poorly designed or positioned, did not produce sufficient air flow, or was vented indoors.

Cooking and gas burners can degrade IAQ by emitting combustion products, pollutants, and excess moisture.[30] Pollutants from cooking include carbon monoxide, nitrogen dioxide, formaldehyde, VOCs, polycyclic aromatic hydrocarbons, fine particulate matter, and ultrafine particles. The 2024 *Ventilation and Indoor Air Quality in Recently Constructed US Homes* study found that kitchen fans were associated with several indicators of improved IAQ, including decreased indoor carbon dioxide, radon, nitrogen dioxide, and formaldehyde.[31] Recent research further substantiated the role of adequate ventilation during cooking in effectively eliminating air pollutants: using kitchen fans reduced the concentration of harmful particles by approximately 2.9 to 4 times compared to spaces without ventilation.[32]

It is important to note that the performance of kitchen fans in residential environments depends on factors such as fan flow rate, positioning, design, and overall kitchen configuration. Given these concerns, in Table 4 we noted that kitchen fans also produced neutral NEIs. For instance, the 2024 *Ventilation and Indoor Air Quality in Recently Constructed Homes* study assessed ventilation systems in 51 homes built since 2013 in three southeastern states.[33] The study found that although kitchen fans were sufficient to improve IAQ when working properly, they were often not ventilated correctly. Over 20 percent of the kitchen range hoods at study homes did not meet the ASHRAE standard for airflow; three more did not vent outdoors, and two did not generate any measurable airflow. An additional source indicated that kitchen fans often do not operate effectively due to poor design and placement of exhaust systems.[34] For optimal pollutant capture, kitchen fans should be well-designed, have sufficient airflow, and be positioned directly above cooktop burners or ovens. Systems with inadequate airflow or improperly placed hoods were less efficient. Overall, kitchen ventilation performed best when located near sources of moisture and pollutants, such as using a range hood or downdraft vent instead of an exhaust fan positioned farther away.

Continue to ensure that all kitchen fans being installed are ASHRAE compliant and installed directly above cooking surfaces. This will ensure the efficient removal of smoke, steam, and harmful pollutants, significantly improving kitchen IAQ.

[29] AIC's Healthier Homes team requested we search specifically for ASHRAE-compliant kitchen fans. We were unable to find NEI research specific to ASHRAE compliant fans, but uncovered other relevant studies included here.
[30] Stratton, Chris J. and Brett C. Singer. *Addressing Kitchen Contaminants for Healthy, Low-Energy Homes.* Lawrence Berkeley National Laboratories. January 2014. https://www.osti.gov/servlets/purl/1129518.
[31] US DOE. *Ventilation and Indoor Air Quality in Recently Constructed U.S Homes.* 2024. Accessed December 5, 2024. https://www.energy.gov/eere/buildings/ventilation-and-indoor-air-quality-recently-constructed-us-homes-measured-data.
[32] Sun, Liu and Lance A. Wallace. "Residential Cooking and Use of Kitchen Ventilation: The Impact on Exposure." *Journal of the Air and Waste Management Association,* 2021, 71, no.7. https://doi.org/10.1080/10962247.2020.1823525.
[33] US DOE. *Ventilation and Indoor Air Quality*.
[34] Ernest Orlando Lawrence Berkely National Laboratory. *Addressing Kitchen Contaminants for Healthy, Low Energy Homes.* January 2014. Accessed December 9, 2024. https://www.osti.gov/servlets/purl/1129518.

MOISTURE AND MOLD REDUCTION MEASURES

"One of the top priorities in building design and operation is moisture control. There is no bigger issue a building faces than water damage…The task of controlling water and moisture dominates our design and construction of the building—everything from rooftop drainage to the curtain wall, to vapor barriers in the basement and dehumidification in the air handler, to placement of water pipes."[35]

CARPET REMOVAL

Removing carpets also removes toxic substances and allergens, including mold and pests. However, research was mixed on the impact of carpet removal alone on reduced allergies and asthma, so it had a neutral NEI on these health outcomes. A small body of research on carpet removal with other measures reported improved lower respiratory health and comfort as well as reduced mold and water damage from such measure bundles.

Research has implicated carpets in IAQ issues that support their removal.[36] A 2020 literature review found that carpets were the primary source of indoor VOCs and emitted a range of other problematic chemicals that themselves may oxidize to form formaldehyde and other dangerous chemicals.[37] A 2018 study assessed the toxicity of carpets made by the six largest manufacturers in the United States by analyzing 12 carpet samples for toxic substances, including nonylphenol, PFAS, and phthalates. Alarmingly, the majority of samples tested positive for at least one toxic chemical, with many containing two or more hazardous substances.[38] Furthermore, carpets harbored dust, microorganisms that can be allergens (e.g., dust mites, bacteria, and fungi), inhalant allergens from these microorganisms, and even cockroaches, rodents, pets, plants, and other animals.[39] Moist carpets, such as those in basements, create conditions hospitable to microbial growth and dust mites. The US Department of Energy (DOE) Building Technologies Program recommended against installing carpet on uninsulated slab basement floors because the carpet traps moisture, which can then harbor mold.[40]

A plausible alternative to carpet removal could be vacuuming. And yet, lab research showed that even extraordinarily rigorous vacuuming (45 minutes vacuuming over the same square meter of carpet) did not fully remove dust, dust mites, fungi, or dust allergens from carpets, and carpets were difficult to decontaminate.[41] Vacuuming itself generated poor IAQ.[42] Instead, eliminating carpets helped improve health concerns associated with various harmful chemicals.[43] Children were particularly vulnerable to health issues stemming from carpets because they spend a significant amount of time on the floor, increasing their exposure to chemicals through hand-to-mouth transfer.[44]

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[35] Allen, Joseph G. and John D. Macomber. *Healthy Buildings: How Indoor Spaces Can Make You Sick—Or Keep You Well.* Harvard University Press, 2022.

[36] We did not search specifically for literature linking carpet removal to reduced trips and falls, another possible NEI of this measure. However, we incidentally uncovered one quasi-experiment that found removing carpets did not reduce trips and falls for people over 65. If AIC is interested in reduced trips and falls, we suggest further research on this topic.

[37] Haines, Sarah E. et al. "Ten Questions Concerning the Implications of Carpet on Indoor Chemistry and Microbiology." *Building and Environment,* 170. March 2020. https://doi.org/10.1016/j.buildenv.2019.106589.

[38] Changing Markets Foundation. *Testing Carpet for Toxics.* Changing Markets Foundation. December 2018. https://changingmarkets.org/wp-content/uploads/2023/10/FINAL-Testing-Carpet-for-Toxics.pdf.

[39] Haines et al. "Ten Questions Concerning Carpet."

[40] US DOE Building Technologies Program. *Building America Top Innovations.*

[41] Haines et al. "Ten Questions Concerning Carpet."

[42] Demanega, Ingrid et al. "Performance Assessment of Low-Cost Environmental Monitors and Single Sensors Under Variable Indoor Air Quality and Thermal Conditions." *Building and Environment,* 2021, 187. https://doi.org/10.1016/j.buildenv.2020.107415.

[43] Changing Markets Foundation. *Testing Carpet for Toxics.* Changing Markets Foundation. December 2018. https://changingmarkets.org/wp-content/uploads/2023/10/FINAL-Testing-Carpet-for-Toxics.pdf.

[44] Changing Markets Foundation. *Testing Carpet for Toxics.*

Nonetheless, research is mixed on the impact of carpet removal on allergies and asthma. Some studies show that removing carpets lowered asthma prevalence, especially when combined with other measures, while other research did not find such effects.[45] The *Home Rx* literature review included two studies with carpet removal as part of the enhanced energy efficiency measure bundle, which also included air sealing, insulation, heating improvements, window/door replacement, upgraded ventilation, and other measures that varied across the two studies.[46] The studies found improved lower respiratory health and comfort, as well as reduced mold and water damage.

DEHUMIDIFIERS

Dehumidifiers were associated with improved home comfort and enhanced long-term durability, though there was no publicly available research supporting these impacts in the Illinois climate. When combined with other measures, dehumidifiers may reduce healthcare utilization and mold, as well as improve comfort.

We located a single study, the 2014 *Evaluation of the Performance of Homes with and without Supplemental Dehumidification*, that highlighted dehumidifiers' potential to enhance living conditions and safeguard homes' longevity because elevated humidity levels can lead to discomfort, poor IAQ, and long-term deterioration of moisture-sensitive materials within a home.[47] However, this study focused on homes in hot and humid climates; its findings may not be generalizable to Illinois.

The *Home Rx* literature review included one study with dehumidifiers included as part of an enhanced energy efficiency measure bundle that also included air sealing, insulation, heating improvements, window/door replacement, ventilation enhancement, carpet removal, pest exclusion, mattress covers, and HEPA vacuums.[48] This comprehensive package of measures yielded reduced healthcare utilization, mold, and improved comfort. Finally, the 2018 *Achieving Health and Social Equity Through Housing* literature review noted that maintaining indoor relative humidity between 30% and 50% can help with mold remediation, though the review did not specifically name dehumidifier as tools to achieve this.[49] The review also did not name NEIs flowing from relative humidity control; it listed NEIs for environmental remediation in general, such as decreased allergy symptoms, reduced dust mites, etc.

HORIZONTAL GUTTERING & EXTERIOR WATER MANAGEMENT

No current research found NEIs from guttering or exterior water management individually. Yet, in combination with other measures, they may increase comfort and air quality and reduce noise, as well as the need to take allergy medications, emergency room visits for bronchitis, unsafe/unhealthy living conditions, mold, and other issues.

Research on NEIs for guttering or external water management was notably scarce; we did not find any studies that met our search criteria for them as standalone measures. We did locate less formal industry sources that made claims about these measures; however, the claims were seemingly inferences stemming from "tried and true" practices in the construction industry or observations based on years of experience working on homes rather than formally researched conclusions. For example, one industry source explained that horizontal guttering directed rainwater away from homes' exterior walls, keeping homes dry.[50] When installed and maintained correctly, guttering

[45] Haines et al. "Ten Questions Concerning Carpet."
[46] Wilson et al. *Home Rx.*
[47] US DOE. *Evaluation of the Performance of Houses With and Without Supplementation Dehumidification*. 2014. Accessed on December 5, 2024 at https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/houses_supplemental_dehumidification.pdf
[48] Wilson et al. *Home Rx.*
[49] Norton, et al. *Achieving Health and Social Equity through Housing*.
[50] Gutters Etcetera. *The Impact of Gutters on Home Energy Efficiency*. October 23, 2023. Accessed December 9, 2024. https://guttersetcetera.com/2023/10/23/the-impact-of-gutters-on-home-energy-efficiency-gutters-etcetera-cincinnati-ohio/.

helped prevent dampness and mold growth. Guttering also safeguarded home foundations and ensured that water did not pool on the roof, which could cause water damage. Properly installed guttering could prevent leaks and heat loss, improving temperature control and comfort while reducing energy bills. Another source emphasized that proper drainage around the home was essential for removing wastewater and sewage, which could contaminate the water supply.[51] If these contaminants were not eliminated, they could create a breeding ground for diseases. Additionally, adequate drainage helped prevent condensation, which can lead to mold and mildew growth. Reducing these allergens not only enhanced comfort but also contributed to the overall health of residents. While these claims were plausible and could be true, we could not find research fitting our search criteria to substantiate them.

In contrast, we did locate two studies featuring guttering and exterior water management in concert with other measures. An evaluation of the NJNG Home Performance with ENERGY STAR program included crawlspace vapor barriers, grading, and gutter repairs to address water intrusion and attic ventilation as part of the health and safety measures allowed in the program.[52] The program had extensive weatherization requirements. Although the evaluation did not call out NEIs for each measure separately, surveyed program participants reported increased comfort, improved air quality, and reduced noise.

Also, a 2018 literature review of NEIs included one study of a program with gutter/downspout measures, the Ohio Residential Energy Assistance Challenge Option (REACH) Program evaluation.[53] REACH is a weatherization program with additional health and safety measures: structural improvements, gutter/downspout repair and grading, environmental cleaning and extermination, and mold and moisture remediation. Pre/post comparisons for program participants compared to nonparticipants found statistically significant reductions in participants needing to take allergy medicines or visit the emergency room for bronchitis, as well as reduced unsafe or unhealthy home conditions; draftiness; smoke in the home; use of kitchen stove/oven for heating; mold in the home, bathroom, or basement; and poison in the home. The evaluation also reported statistically significant improvements in the use of exhaust fans while showering.

MOLD REMEDIATION

Mold remediation measures varied widely and were sometimes associated with reduced asthma among already asthmatic children. Measure packages with mold removal were linked to several direct and indirect NEIs, including reduced asthma symptoms and sick days taken, but also improved comfort, rest, sleep, and personal finances. Mold remediation had mixed results on IAQ, which we deemed a neutral NEI.

In our literature search, we sought to find NEIs specific to direct mold removal actions, pithily summed up by the EPA as follows: “To solve a mold problem, get rid of the source of the moisture and clean up the mold.”[54] We did not find studies of NEIs of individual mold removal measures but rather comprehensive packages of mold removal activities. Such mold remediation measures were broad and overlapped considerably with other Healthier Homes measures. Therefore, we categorized all mold remediation measures as “with other measures” in Table 4. The 2018 *Achieving Health and Social Equity Through Housing* literature review synthesized the following list of effective measures to mitigate the presence of biological contaminants (including mold) and unsanitary home living conditions:

- Kitchen and bathroom exhaust fans venting to the outside

[51] Gors, Iain. *The Importance of Proper Drainage Systems for your Home's Health*. Healthy Building Science, 2023. Accessed December 9, 2024. https://healthybuildingscience.com/2023/03/02/effective-residential-drainage-systems/.
[52] NJNG. *NJNG Home Performance with ENERGY STAR*.
[53] Connecticut Energy Efficiency Board. *R1709 Connecticut Non-Energy Impacts Literature Review.* Prepared by APPRISE Inc. August 2018. Connecticut-Non-Energy-Impacts-Report.pdf.
[54] EPA. *Guide to Air Cleaners.*

- Venting clothes driers outside
- Maintaining indoor relative humidity between 30% and 50%
- Drying off wet surfaces
- Addressing water leaks
- Thoroughly cleaning and drying water-damaged carpets and building materials within 24 hours, or consider their removal or replacement
- Clean regularly to reduce dust mites, pollen, animal dander, and other allergens
- Ventilate attics and crawl spaces
- Regularly clean and dehumidify basements
- Clean and maintain all appliances that directly contact water (including HVAC and dehumidifiers).[55]

The review did not pinpoint NEIs specific to these measures; instead, it summarized NEIs for environmental remediation in general, such as decreased allergy symptoms, reduced dust mites, and more.

Similarly, the 2015 *Research Agenda on Assessing and Remediating Home Dampness and Mold* included a thorough literature review of the role of dampness and mold in home occupant health.[56] The review described a single study examining reductions in severe childhood asthma among asthmatic children in 29 mold-remediated homes. The specific mold remediations were customized to each home but included repairs that reduced water infiltration, removal of water-damaged materials, HVAC system repair/alteration, cleaning mold from hard surfaces, exhausting water vapor from kitchens and bathrooms, disconnecting and redirecting downspouts, reducing moisture in crawlspaces and basements, and repairing plumbing leaks. The study reported a 90% reduction in severe asthma exacerbations among asthmatic children. Overall, though, the *Research Agenda*'s literature review concluded there was sufficient evidence for the association between dampness and mold for several respiratory illnesses but only sufficient *causal* evidence for their role in exacerbating childhood asthma among fungally sensitized children. Additionally, the review found that "the overall scientific evidence on what specific remediation strategies are necessary and sufficient to protect health is very limited."

A few studies included mold remediation with other measures such as improved lighting, air sealing, insulation, and heating system replacements. The *HomeR$_x$* literature review included one study examining mold removal in combination with other measures characterized as "enhanced energy efficiency," including insulation, air sealing heating repair/replacement, window/door replacement, ventilation (an ERV and exhaust), plus supplemental fans, carbon monoxide alarms, and a stand-alone HEPA filter.[57] Occupants reported better comfort but mixed results on IAQ.

RIM JOIST INSULATION

We found limited research on rim joist insulation NEIs. However, a few studies suggested rim joist insulation reduced drafts, condensation, water damage, maintenance concerns, mold, rot, and odors.

Rim joists, also known as rim boards, band joists, or band boards, support the home's foundation by holding up the floor system and providing a barrier against the outside elements. Research on the NEIs related to rim joist insulation was rare; we found three publications addressing NEIs of this measure, only one of which was a formal

[55] Norton, et al. *Achieving Health and Social Equity through Housing*.
[56] Mendell, Mark J. *A Research Agenda on Assessing and Remediating Home Dampness and Mold to Reduce Dampness-Related Health Effects*. Lawrence Berkeley National Laboratory. June 15, 2015. https://escholarship.org/uc/item/5cx8t259.
[57] Wilson et al. *Home R$_x$*.

research study. Rim joist insulation may play a role in moisture prevention by serving as a barrier against drafts,[58] and preventing condensation on the interior of the rim joist.[59] This enhanced insulation and reduced water damage as well as subsequent maintenance concerns in the home. Also, a 2013 summary of basement insulation measures from the DOE's Building Performance Program stated rim joists should be air sealed and insulated to prevent condensation, which can lead to mold, rot, and odor problems.[60]

VAPOR BARRIERS

There was very little research on the NEIs of vapor barriers, and none of the sources we located included empirical evidence of NEIs for vapor barriers. Consequently, our literature review is inconclusive on the NEIs of vapor barriers.

Vapor barriers, also known as water-resistive barriers, prevent water vapor from penetrating walls, ceilings, and floors. As with guttering and exterior water management, we found scant recent research on NEIs for this measure but several claims by industry market actors about them. The *Achieving Health and Social Equity Through Housing* literature review noted that vapor barriers were a radon mitigation measure used in the WAP program; however, it did not provide research showing links between vapor barriers and the prevention of radon getting into homes or basements.[61] Similarly, the DOE Building Technologies Program described a caveat about vapor barriers on basement walls: if an impermeable vapor barrier such as plastic is used inside basement walls, the walls can absorb large amounts of moisture from outside and stay chronically damp.[62] In cold climate areas, freeze-thaw cycles can damage damp basement walls. Other Class I vapor retarders create the same problems; therefore, polyethylene sheeting, vinyl or foil wallpaper, or epoxy, oil, or alkyd paint should not be used on interior basement walls. However, this DOE source did not include citations or explain the empirical basis for any of these claims, and we can only infer possible NEIs.

As mentioned, we found industry sources with many claims about vapor barriers. For instance, one well-known home improvement website claimed they help reduce moisture levels in homes, leading to lower humidity and a decrease in dust mites and other allergens.[63] This, in turn, creates a drier environment, ultimately improving overall air quality. Dry insulation also provided increased comfort and improved temperature control in the home, creating a more pleasant living environment. Another industry source explained moisture in the air can hinder our bodies' ability to regulate temperature.[64] When moisture levels are stable, the temperature in the home will stay more consistent, making it more comfortable for residents. Reduced moisture also reduces mold growth because mold builds up in moist areas, such as walls and other hidden areas. According to this source, vapor barriers serve multiple purposes: they mitigate moisture levels within the home, effectively deter pests such as ants, termites, bees, wasps, and cockroaches (which frequently enter through small openings in homes' envelopes), and can fortify buildings against radon penetration. We were unable to substantiate any of these claims. Therefore, our search for vapor barrier NEIs was inconclusive.

[58] ICF International. *Quantification of Non-Energy Impacts for Residential Program*. March 31, 2017. Accessed December 4, 2024. https://bit.ly/3XkD1xV

[59] Dickson, Emily et al. *Durability Evaluation of Insulated Rim Joists.* Pennsylvania Housing Research Center. June 2016. https://www.phrc.psu.edu/assets/docs/Publications/Durability-Evaluation-of-Insulated-Rim-Joists-FINAL.pdf.

[60] US DOE Building Technologies Program. *Building America Top Innovations*.

[61] Norton et al., *Achieving Health and Social Equity through Housing.*

[62] US DOE Building Technologies Program. *Building America Top Innovations*.

[63] Childs, Mel. *Understanding Moisture Barriers.* August 28, 2024. *https://www.thisoldhouse.com/walls/87464/vapor-moisture-barriers*.

[64] Attainable Home. *The Pros and Cons of Using a Vapor Barrier.* October 19, 2022. Accessed December 17, 2024. https://www.attainablehome.com/the-pros-and-cons-of-using-a-vapor-barrier/.

KEY FINDINGS

We present key findings from our program design review and NEI research below:

- **Finding #1:** All 20 comparable programs sought to generate NEIs, though just two of the programs had assessed NEIs through formal means, such as a program evaluation.
- **Finding #2:** The majority of programs (60%) targeted low income individuals. Additionally, almost half (45%) were designed to benefit individuals with respiratory issues, and a quarter (25%) specifically aimed to support children. Only 20% targeted the combination of low income with respiratory issues.
- **Finding #3:** Programs most commonly collaborated with nonprofit organizations (35%), while a quarter (25%) collaborated with local health departments and government.
- **Finding #4:** All programs incorporated home assessments to identify health hazards and improvement opportunities, including the need for specific safety devices and potential whole-home upgrades.
- **Finding #5:** Over half of the programs (60%) offered extensive home upgrades, such as insulation and equipment updates. In contrast, those unable to provide such upgrades directly often referred customers to other organizations for assistance, highlighting a collaborative approach.
- **Finding #6** More than half (55%) of the programs emphasized the importance of education, offering either informative materials or direct contractor-led education to improve residents' understanding of home safety and maintenance.
- **Finding #7:** The most common program measures we uncovered were removing lead, mold, or other health hazards contributing to respiratory issues, such as asthma, with nearly half (45%) of the programs undertaking these efforts. This was followed by water conservation measures and equipment upgrades, each cited by about one-third (35%) of the programs. Other measures included air sealing, smoke and carbon monoxide detectors, and air purifiers, with air quality monitors being the least provided measure, mentioned by only 15% of the programs.
- **Finding #8:** The Healthier Homes measures have many potential positive NEIs, including improved comfort, improved health, reduced external noise entering the residence, more consistent indoor environment (via temperature and humidity control or reduced air leakage), improved overall well-being, reduced sick days or absenteeism from work or school, reduced moisture or water damage, and more.

CONCLUSIONS AND RECOMMENDATIONS

- **Conclusion #1**: AIC's Healthier Homes Channel is already implementing all six of the best practices used by similar programs.
- **Conclusion #2**: The research available on NEIs from some Healthier Homes Channel measures is limited, at least when constraining the search to the criteria we used.
  - **Recommendation 2a:** Consider a more extensive literature search for measures especially important to AIC and its stakeholders or for priority NEIs such as reduced asthma.
  - **Recommendation 2b**: Consider a more formal study of priority NEIs as part of channel implementation to confirm benefits for program participants and communities. Integrate pre- and post-measurements of possible impacts and benefits into program delivery to build a stronger evidence base while minimizing program expenses. The channel is already installing IAQ monitors and collecting data from them, which is a promising start.

    - **Recommendation 2c**: Consider collecting long-term pre- and post-health outcome data alongside IAQ data. The research suggesting IAQ has neutral impacts on health includes a small number of studies, sometimes tracking only short-term health improvements. Collecting additional pre- and post-data could allow for more sophisticated and nuanced analyses. A health or medical research partner may provide valuable guidance to any such research to ensure health data are appropriately collected and safeguarded.
- **Conclusion #3**: Though limited, the research base suggests channel measures may offer NEIs, and the various measures may work in complementary ways to augment positive impacts.
    - **Recommendation 3a**: Articulate the theories of change linking measures to specific NEIs, including indirect and direct impacts and benefits. For example, create diagrams showing how certain Healthier Homes Channel measures may individually and interactively support improved air quality, thermal comfort, etc. These theories of change could help prioritize measures or NEIs for implementation or further study.
    - **Recommendation 3b**: If possible, assess the accuracy of the theories of change by evaluating the interactive effects of measures brought to bear on the same goal (e.g., IAQ). Such a study could identify the relative effectiveness of the measures. Pinpointing redundant measures or those that garner the largest impact on IAQ, for example, could enable AIC and its partners to streamline the number of measures provided or provide useful information to consider when selecting the measures to install at a particular residence, given its unique needs.
- **Conclusion #4**: Although nearly all of the measures examined have the potential for positive NEIs, several also have neutral impacts (alone or in combination with other measures), and one had negative impacts in combination with other measures.
    - **Recommendation 4a**: Work to ensure measure implementation avoids neutral and negative impacts, such as by training implementer staff on effective equipment, installing kitchen fans, and radon risk of air sealing with other measures, among others.

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APPENDIX

Table 5. Programs Reviewed in Program Design Review

Program	Location
The Healthy Homes Program	National
Healthy Homes for Healthy Families: A Cook County and Elevate Initiative	Cook County, Illinois
Healthy Homes Program	Tampa, Florida
Healthy Homes Program	Nicor Gas Service Territory
Healthy Homes Asthma Program	Massachusetts
Community Asthma Prevention Program (CAPP)	Philadelphia and parts of Delaware and Montgomery counties, Pennsylvania
The Bay Area Healthy Homes Initiative (BAHHI)	Contra Costa and Alameda County, California
Green and Healthy Homes Program	San Antonio, Texas
Green and Healthy Homes Program	Salt Lake County, Utah
Healthy Homes Initiative	Arizona
Healthy Homes Program	Nevada
Healthy Homes Program	Gwinnett, Georgia
Healthy Homes Program	Cook County, Minnesota
Priority Health Asthma Program	Michigan
Healthy Homes Iowa	Polk County, Iowa
The Healthy Homes Production Grant Program	New Castle County, Delaware
Healthy Homes Roanoke	Roanoke, Virginia
The Healthy Homes Pilots	Vermont
The Massachusetts Healthy Homes Program	Massachusetts
Healthy Neighborhoods Program	New York

Table 6. Search Terms for Healthier Homes NEI Research

Measures	Search Terms
Air Sealing	▪ Air Sealing Non-Energy Impact Evaluation ▪ Air Sealing Non-Energy Impacts Study ▪ Air Sealing Health Benefits
Dehumidifier	▪ Dehumidifiers Non-Energy Impact Evaluation ▪ Dehumidifier Non-Energy Impacts Study ▪ Dehumidifier Market Research ▪ Dehumidifier Health Benefits
Air Purifier	▪ Air Purifier Non-Energy Impact Evaluation ▪ Air Purifier Non-Energy Impacts Study ▪ Air Purifier Market Research ▪ Air Purifier Health Benefits
Energy Recovery Ventilators (ERVs)	▪ ERV Non-Energy Impact Evaluation ▪ ERV Non-Energy Impacts Study ▪ ERV Market Research ▪ ERV Health Benefits

Measures	Search Terms
Kitchen Fan	▪ Kitchen Fan Non-Energy Impact Evaluation ▪ Kitchen Fan Non-Energy Impacts Study ▪ Kitchen Fan Market Research ▪ Kitchen Fan Health Benefits
Carpet Replacement	▪ Carpet Replacement Non-Energy Impact Evaluation ▪ Carpet Replacement Non-Energy Impacts Study ▪ Carpet Replacement Market Research ▪ Carpet Replacement Health Benefits ▪ Carpet Replacement Health Research
Mold Remediation	▪ Mold Non-Energy Impact Evaluation ▪ Mold Non-Energy Impacts Study ▪ Health Hazards Non-Energy Impact Evaluation ▪ Health Hazards Non-Energy Impacts Study ▪ Mold Remediation Utility Market Research ▪ Mold Removal Non-Energy Impact Evaluation ▪ Mold Mitigation Impact Evaluation
Horizontal Guttering	▪ Horizontal Guttering Non-Energy Impact Evaluation ▪ Horizontal Guttering Non-Energy Impacts Study ▪ Horizontal Guttering Market Research ▪ Horizontal Guttering Health Benefits ▪ Downspouts Impact Evaluation ▪ Downspouts Impact Study
Exterior Water Management	▪ Flood Control Non-Energy Impact Evaluation ▪ Flood Control Non-Energy Impacts Study ▪ Flood Control Market Research ▪ Exterior Drains Market Research ▪ Exterior Drains Health Benefits ▪ Residential Drainage Health Benefits Study
Vapor Barrier	▪ Vapor Barrier Non-Energy Impact Evaluation ▪ Vapor Barrier Monitor Non-Energy Impacts Study ▪ Vapor Barrier Health Benefits ▪ Moisture Barrier Impact Study ▪ Moisture Barrier Health Benefits ▪ Vapor Intrusion Non-Energy Impacts
Rim Joist Insulation	▪ Rim Joist Non-Energy Impact Evaluation ▪ Rim Joist Non-Energy Impacts Study ▪ Rim Joist Non-Energy Impact Evaluation ▪ Rim Joist Health Benefits ▪ Band Joist Impact Study ▪ Band Joist Impact Evaluation