JANUARY 2022

Insulation and Air Sealing in Low-Income Multifamily Energy Efficiency Programs:

Current State, Challenges, and Opportunities to Use Safer Materials

ENERGY EFFICIENCY FOR ALL

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ABOUT ENERGY EFFICIENCY FOR ALL

Energy Efficiency for All unites people from diverse sectors and backgrounds to collectively make affordable multifamily homes energy and water efficient. We do this work so people in underinvested and marginalized communities—particularly Black, Latino, and other communities of color—can equitably benefit from the health, economic, and environmental advantages of energy and water efficiency. Reducing energy and water use in affordable multifamily housing will improve the quality of life for millions, preserve affordable housing across the country, reduce the energy burden on those who feel it the most, and cut carbon pollution.

ABOUT HEALTHY BUILDING NETWORK

Since 2000, Healthy Building Network (HBN) has defined the leading edge of healthy building practices that increase transparency in the building products industry, reduce human exposure to hazardous chemicals, and create market incentives for healthier innovations in manufacturing. We are a team of researchers, engineers, scientists, building experts, and educators, and we pursue our mission on three fronts:

1. Research and policy—uncovering cutting-edge information about healthier products and health impacts;

2. Data tools—producing innovative software platforms that ensure product transparency and that catalog chemical hazards; and

3. Education and capacity building—fostering others' capabilities to make informed decisions.

As a nonprofit organization, we do work that broadly benefits the public, especially children and the most marginalized communities, who suffer disproportionate health impacts from exposure to toxic chemicals. We work to reduce toxic chemical use, minimize hazards, and eliminate exposure for all.

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Table of Contents

ACKNOWLEDGMENTS

This report was made possible through the generous support of The JPB Foundation. The authors gratefully acknowledge the external reviewers, internal reviewers, colleagues, and partners who supported this study. Many thanks to Elise Marton and Tanja Bos for their skilled help in producing this report.

We would like to thank everyone who took the time to share their knowledge through email correspondence or conversations, including:

Megan Ching, Association for Energy Affordability

Logan Atkinson Burke, Alliance for Affordable Energy

Jackie Dadkis, Green Coast Enterprises

Lisa Rafferty, Applied Energy Group

Becky Olson, Center for Energy and Environment

Andrew Linhares, Renew Missouri

Ravi Malhotra, ICAST

Mike Thomas, Minnesota Housing

Lance Collins, Partner Energy

Michael Miranda, BlueGreen Alliance

And a special thank-you to Amanda Gramigna and Chris Steinhoff at Elevate Energy for several early conversations on this project and the materials survey, and for working with their contractors to help us better understand the materials they use.

DEFINITIONS

Building Enclosure: The parts of a building that physically separate the exterior environment from the interior environment(s). Generally consists of the roof system(s), the above-grade wall system(s) including windows and doors, the below-grade wall system(s), and the base floor system(s).

Contractor/Subcontractor: Someone hired by an implementer or building owner to perform work in a building as part of an energy efficiency program.

Implementer: Private or nonprofit organization with energy efficiency expertise, contracted by the program administrator to implement energy efficiency projects.

Indoor Environmental Quality (IEQ): The quality of a building's interior environment in relation to the health and well-being of those who occupy space within it.

Low-Income Multifamily Energy Efficiency Program: A state- or customer-funded energy efficiency program serving buildings with multiple units whose residents qualify as low-income according to specific criteria (see Appendix 2 for more details).

Program Administrator: Utility, nonprofit organization, or company responsible for overseeing the design and implementation of energy efficiency programs.

Executive Summary

Investing in energy efficiency (EE) upgrades to existing buildings has the potential to deliver substantial benefits to building owners, residents, and the environment by reducing emissions from energy use, lowering energy bills, and improving comfort. Insulation and air sealing are two key upgrade measures that lead to better-performing buildings. Unfortunately, some of the materials used in EE upgrades contain chemicals that can contribute to adverse health impacts. These chemicals of concern can pose threats to a building's residents and to the workers who manufacture, install, and dispose of the products, as well as to the communities adjacent to the manufacturing facilities.

To identify opportunities and challenges for advancing healthier insulation and air-sealing material use in low-income multifamily EE upgrades, we conducted interviews and gathered publicly available information from EE programs to understand whether and how insulation and air sealing are currently done in multifamily buildings. We considered EE programs that support comprehensive upgrades requiring a building to be unoccupied, and programs that perform upgrades in occupied buildings only.

We found that many programs include insulation and air sealingrelated to pipes and ducts. In contrast, HVAC (heating, ventilation and air-conditioning) systems and particular building enclosure insulation and air sealing measures are often not included in EE upgrades of low income multifamily buildings, especially in programs that perform upgrades in occupied buildings. There are a variety of reasons for this. Unlike typical single-family EE programs, some multifamily EE programs do not allow building enclosure insulation or air sealing measures.

Other programs may allow these measures but do not adequately support their installation (i.e., incentives are not robust). Even if allowed under EE programs, one significant challenge is that many impactful building enclosure insulation and air-sealing measures require access to the residential units, which can be intrusive to occupants, or may require large portions of a building to be unoccupied. Exterior building shell insulation offers an opportunity to overcome this challenge but may not be possible because of a building's facade. If building enclosure insulation measures are included in an upgrade, attic insulation is most common. Blown fiberglass and cellulose insulation (preferred materials from a health hazard perspective) are common for this application.

There are many challenges to the inclusion of insulation and air-sealing measures in low-income multifamily housing upgrades and to ensuring that safer materials are used. These include current EE program designs that fail to support implementation of these measures, lack of strong program technical specifications, the fragmented nature of program implementation, and a lack of state-level data collection and report standardization.

There are also many opportunities to broaden the use of insulation and air sealing in EE programs and ensure that safer materials are used. Our recommendations are to:

- Improve EE program specifications to prohibit use of hazardous chemicals in EE upgrades, including in the materials used for air sealing and insulation;
- Improve data collection and standardize reporting on the materials used in EE upgrades, the type and amount (square footage) of each measure (including insulation and air sealing) installed in projects, and resulting total energy savings;
- Update EE program structures to robustly incentivize HVAC and building enclosure insulation and air-sealing measures in low-income multifamily buildings; and
- Conduct research to expand the evidence on EE and indoor environmental quality benefits of HVAC and building enclosure insulation and air sealing in low-income multifamily housing.

Background

Our interior spaces have an enormous impact on our health and productivity. From designing for an active lifestyle to proper lighting, insulation, and acoustics, how we build matters. One often overlooked aspect of how buildings influence people's health are the chemicals found in building materials.

There are limited regulations on chemicals used in building products, and unfortunately there are toxic chemicals found in some everyday building materials that have the potential to harm human and environmental health.

Evidence increasingly shows that toxic chemical exposures in general are costing the United States billions of dollars and millions of IQ points.[1] Although these toxic chemicals affect all of us, they are disproportionately impacting the health of children, communities of color, and low-income families.[2]

As Energy Efficiency for All (EEFA) works to ensure that residents of affordable multifamily housing see the benefits of energy efficiency (EE) improvements, it is important to consider the potential health impacts of materials and ensure that safer materials are used.[3]

The story of fiberglass batt insulation illustrates how a single material can have a range of impacts on residents, workers, and the environment; it also shows how market demand can improve the safety of available materials. For a long time, formaldehyde-based binders were standard in fiberglass batt insulation. Even though formaldehyde was identified as "reasonably anticipated to be a human carcinogen" in 1981 by the U.S. National Toxicology Program, its use in fiberglass insulation continued to be prevalent for decades. Although insulation is typically installed behind drywall or other barriers, formaldehyde from insulation can still enter living spaces and expose residents.[4] In addition, the impacts of hazardous chemicals extend beyond building occupants. Workers along the supply chain and communities near production facilities can also be affected. Factories manufacturing fiberglass insulation in the United States and Canada released nearly 600,000 pounds of formaldehyde into the air in 2005.[5] Fortunately, market pressure for healthier alternatives, including improved green building certifications, has since driven residential fiberglass

1 Teresa M. Attina et al., "Exposure to Endocrine-Disrupting Chemicals in the USA: A Population-Based Disease Burden and Cost Analysis," *The Lancet* 4, no. 12 (December 1, 2016): 996–1003, https://doi.org/10.1016/S2213-8587(16)30275-3. Julia Malits et al., "Perfluorooctanoic Acid and Low Birth Weight: Estimates of US Attributable Burden and Economic Costs From 2003 Through 2014," *International Journal of Hygiene and Environmental Health* 221, no. 2 (2017), https://doi.org/10.1016/j.ijheh.2017.11.004.

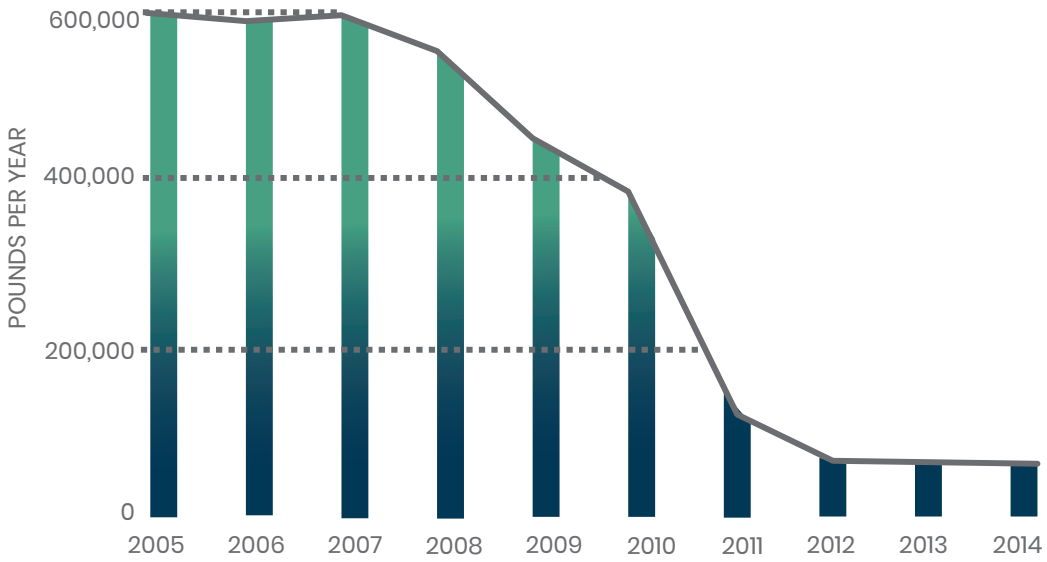
2 Michael Gochfeld and Joanna Burger, "Disproportionate Exposures in Environmental Justice and Other Populations: The Importance of Outliers," *American Journal of Public Health* 101, Suppl. 1 (December 2011): S53–63, https://doi.org/10.2105/AJPH.2011.300121. Michelle L. Bell and Ebisu Keita, "Environmental Inequality in Exposures to Airborne Particulate Matter Components in the United States," *Environmental Health Perspectives* 120, no. 12 (December 1, 2012): 1699–1704, https://doi.org/10.1289/ehp.1205201. U.S. Environmental Protection Agency, *Environmental Equality: Reducing Risk for All Communities, Volume 1: Workgroup Report to the Administrator*, June 1992, https://www.epa.gov/sites/production/files/2015-02/documents/reducing_risk_com_vol1.pdf.

3 Energy Efficiency for All, "Achieving Energy Efficiency for All Renters," https://www.energyefficiencyforall.org/ (accessed October 17, 2021).

4 Tom Lent, "Formaldehyde Emissions From Fiberglass Insulation With Phenol Formaldehyde Binder," Healthy Building Network, August 26, 2009, http://healthybuilding.net/uploads/files/formaldehyde-emissions-from-fiberglass-insulation-with-phenol-formaldehyde-binder.pdf.

5 James Vallette, "Residential Fiberglass Insulation Transformed: Formaldehyde Is No More," Healthy Building Network, October 30, 2015, https://healthybuilding.net/blog/204-residential-fiberglass-insulation-transformed-formaldehyde-is-no-more.

Figure 1. Formaldehyde releases from residential fiberglass insulation factories in the United States and Canada, 2005–2014.



Graph based on U.S. Environmental Protection Agency Toxics Release Inventory and Canadian National Pollutant Release Inventory data.

batt insulation manufacturers in the United States and Canada to phase out formaldehyde-based binders in favor of less hazardous alternatives. This change reduces exposure to formaldehyde for both residents and those impacted throughout the supply chain. The market shift led to a 90 percent drop in formaldehyde emissions from manufacturing facilities as of 2014 (see Figure 1).[6]

While the building products industry has seen several such transitions away from hazardous chemicals in specific materials, there are unfortunately still other chemicals of concern in products, including insulation and air-sealing materials.

Factories manufacturing fiberglass insulation in the United States and Canada released nearly 600,000 pounds of formaldehyde into the air in 2005.

6 Ibid.

Summary of Previous Work

In 2016, EEFA convened the Healthy Affordable Building Materials project with the overarching goal to improve indoor environmental quality (IEQ) through the use of nontoxic building products.[7] We focused on insulation and air sealing as interventions that deliver energy savings and comfort benefits to occupants and are a part of many EE programs. The first research project consisted of EEFA partners Natural Resources Defense Council (NRDC) and Elevate Energy, as well as Healthy Building Network (HBN), Three3, and Vermont Energy Investment Corporation. The goals of the project included capturing a snapshot of insulation and air-sealing materials being used, comparing the hazardous content in these different materials, and providing recommendations around safer materials selection.

We found that a wide range of insulation and air-sealing materials may be used for a variety of applications both as part of the building enclosure and elsewhere (Table 1). The building enclosure comprises the parts of a building that physically separate the exterior environment from the interior environment(s) and generally consists of

Table 1. Insulation and air-sealing measures in the building enclosure and other locations.

Part of building	Insulation measure	Air-sealing measure
Building enclosure	Attic Exterior continuous Unit exterior wall Basement Crawl space	Roof cavity Windows/doors—exterior and interior HVAC/plumbing/electrical penetrations—exterior and interior Foundation
Other	Pipes HVAC (heating, ventilation, and air-conditioning) ducts	HVAC ducts

7 Energy Efficiency for All, "Healthy Affordable Building Materials," https://www.energyefficiencyforall.org/initiatives/healthybuildingmaterials/ (accessed October 17, 2021).

the roof system(s), the above-grade wall system(s) including windows and doors, the below-grade wall system(s), and the base floor system(s).

Building from the hazardous chemical content that was identified in this research, Table 2 shows the current recommendations for insulation and air-sealing materials used in EE upgrades.[8]

Additional details and resources from this previous work can be accessed online.[9]

Table 2. Summary of current recommendations for healthier insulation and air-sealing materials.

Insulation

- Prefer fiberglass, formaldehyde-free mineral wool, and cellulose building insulation
- Prefer formaldehyde-free fiberglass or polyethylene foam pipe insulation
- Use formaldehyde-free duct insulation
- Prefer unfaced insulation when possible
- Avoid foam insulation, whether board or spray-applied
- If board insulation is required, prefer expanded cork, halogen-free polyisocyanurate, or rigid mineral wool insulation
- Use mechanical installation methods, such as fasteners, to avoid unnecessary use of adhesives

Air sealing

- Prefer caulk-type sealants over spray foam sealants
- Prefer foam sealing products that are not reacted on site, like foam sealant tape or backer rod, instead of a spray foam sealant
- Avoid phthalate plasticizers
- Prefer acrylic-based sealants with very low levels of volatile organic compounds (VOCs)—options with ≤ 25 grams per liter (g/L) are available for many applications
- Prefer foil-backed butyl tape for HVAC sealing—if you must use mastic, ask manufacturers for content information to avoid halogenated flame retardants, and prefer no-VOC products
- Avoid products that are marketed as antimicrobial and claiming or implying a health benefit

8 Healthy Building Network, "Insulation Hazard Spectrum," https://homefree.healthybuilding.net/products/22-insulation-hazard-spectrum (accessed October 17, 2021). Healthy Building Network, "Sealant Hazard Spectrum," last updated July 16, 2018, https://homefree.healthybuilding.net/products/55-sealant-hazard-spectrum. (Accessed October 17, 2021)

9 Energy Efficiency for All, "Healthy Affordable Building Materials."

Goals for This Report

In 2020, NRDC began collaborating with HBN to conduct further research around the use of healthier insulation and air-sealing materials in low-income multifamily buildings. The original goals of this project were to:

- Provide reliable quantitative estimates of the types of insulation and air-sealing materials used in EE upgrades performed through low-income multifamily programs for which EEFA advocates funding;
- Understand where material decisions are made;
- Identify leading programs and organizations using healthier materials; and
- Determine the biggest-impact opportunities for shifting to healthier materials.

Throughout the research process, we encountered several challenges that made a reliable quantitative estimate unlikely. We therefore adjusted the primary goal, aiming instead to use interviews and publicly available information from low-income multifamily EE programs to:

- Understand whether and how insulation and air sealing are done; and
- Highlight opportunities and challenges for advancing healthier insulation and air-sealing material use in these programs.

The following sections outline our approach to data collection, our findings, and challenges and opportunities moving forward.

Approach

Energy Efficiency Programs

EEFA works in the following states: Maryland, New York, Pennsylvania, Illinois, Michigan, Minnesota, Missouri, Louisiana, North Carolina, Virginia, and California. We searched for publicly available information about EE programs in these states that 1) targeted low-income multifamily housing and 2) performed upgrades in 2019. This search yielded 38 programs. We considered sources including annual reports produced by program administrators and implementers to find data on the size of these programs and the portion of program funds allocated to installation of insulation and air-sealing measures. The goal was to understand what information is publicly available and to identify programs with the greatest use of insulation and air-sealing materials to target for a materials survey. We also developed a spreadsheet-based survey to collect information on the insulation and air-sealing materials used for a range of energy efficiency upgrade applications. The plan was to have initial conversations with the implementers to understand who influences material decisions for the EE programs they implement, and then provide the survey to the party or parties who have knowledge of the specific materials used. We developed and piloted the survey with EEFA partner and Illinois program implementer Elevate Energy. We received responses from three contractors with whom Elevate Energy works and adjusted the survey based on their feedback. The adjusted survey is reproduced in Appendix 1.

Through EEFA's network of state coalitions, we had initial conversations with a few program implementers to try to understand the scope of insulation and air sealing done and who makes material decisions. After gathering information from several states, it was clear that a true quantitative understanding of insulation and air-sealing materials would be exceedingly time-consuming. Ultimately, we selected program implementers in California, Illinois, Louisiana, Minnesota, and Missouri for more in-depth discussions to develop a preliminary understanding of some of the challenges and opportunities for insulation and air sealing in multifamily EE upgrades.

We generated a list of 18 EE programs in these five states (including their administrators and implementers) that targeted low-income multifamily housing and had performed upgrades in 2019. The programs are listed in Appendix 2.

Programs had varying definitions of *multifamily*, with a building of at least 5 units being the most common. Programs also used different criteria for *low-income*, with most having income requirements (such as no more than 80 percent of Area Median Income) for some proportion of building residents. Some programs served properties receiving federal assistance, and others had a mix of criteria related to federal assistance and resident income (Appendix 2).

We also reviewed publicly available information on upgrades performed through the Low-Income Housing Tax Credit (LIHTC) program and spoke with staff at a state housing finance agency (Appendix 3).

Technical Considerations

To gain additional insight into technical challenges to the implementation of insulation and air-sealing measures in multifamily housing, we also conducted semi-structured interviews with energy efficiency upgrade technical experts.

Findings

Overall, we found that data are not readily available on which projects include insulation and/or air-sealing measures, the materials specified, and any green building certification pursued. Based on the limited publicly available information and our conversations with many individuals involved in EE upgrades, below is a list of findings regarding the reviewed EE programs, followed by technical considerations for insulation and air sealing in multifamily housing. Findings on LIHTC are given in Appendix 3.

Energy Efficiency Programs

Data collection, reporting, and transparency

- Program reports lack standardization, not only across different states but within the same state. For example, some programs indicate the number of projects that include insulation and air sealing, some report the square footage of insulation and linear footage of air sealing completed, some report the number of measures completed, and some do not report anything quantitative about insulation or air sealing.
- No programs reviewed for this study report publicly on the materials used in upgrades. Only one of the implementers we spoke with internally tracks some information about materials.
- We were unable to find public reports for some programs.

Program delivery and design

- Some programs, like California's Low Income Weatherization Program for Multifamily Properties (LIWP-MF), can be part of refinancing, with EE upgrades occurring concurrent with other major upgrades, necessitating resident relocation so that the upgrades can take place in an unoccupied building. Most customer-funded programs are separate from refinancing, with upgrades taking place in occupied buildings.
- EE program implementation and delivery structures vary, and these structures may be determined by states, utilities (for customer-funded programs), or a combination of the two. In one model, implementers work directly with contractors who do the upgrade work. In another model, implementers do not work directly with contractors but work with building owners instead (see Figure 2).

Programs vary greatly in terms of which insulation and air-sealing measures are allowed (Appendix 2). Some permit HVAC and/or building enclosure insulation and air-sealing measures, while others do not.

- If allowed, the use of insulation and air-sealing measures in upgrades varies across programs. Some implementers report that projects consistently include air sealing and attic cavity insulation, while others do not. For example, one Minnesota implementer noted that while building enclosure insulation and air-sealing measures are allowed, they are not usually done for multifamily buildings larger than 20 units, except for attic insulation. In contrast, roof cavity air sealing is reportedly a priority for projects in hot and humid Louisiana.

Insulation and air-sealing materials used in EE upgrades

- Some programs or implementers have specifications for the types of materials that may be used, including chemical content. For example:
  - The Association for Energy Affordability (AEA), the implementer of California's LIWP-MF, has technical specifications (see Appendix 4). From a healthier materials perspective, AEA specifies:
    - Formaldehyde-free blown insulation and fiberglass batt insulation.
    - Unfaced fiberglass batts for several applications instead of faced batts, which may contain chemicals of concern.
    - Low-VOC water-based duct mastic for duct sealing.
  - The California Energy Savings Assistance Program (ESAP) has installation standards.[10] From a healthier materials perspective, ESAP specifies:
    - Mineral fiber batts and loose fill (includes fiberglass), cellulose loose fill, and foil-faced polyisocyanurate or high-density fiberglass board as approved materials.[11]
    - "Sealants applied indoors shall be non-toxic," though this is not defined.[12]
- At least one administrator of the ESAP program bulk-purchases blown cellulose, blown fiberglass, and unfaced fiberglass batt insulation.[13]
- Some EE programs only specify EE performance standards, such as R-value (thermal resistance) requirements for insulation, leaving the choice of materials that meet the requirements up to the contractors.
- Across programs, if insulation measures are installed, attic insulation with blown fiberglass or cellulose is most common.
- Extruded polystyrene (XPS) and polyisocyanurate were reported as sometimes used for attic hatch insulation.
- Rigid roof insulation is part of some upgrades. Materials used include closed cell spray foam and "rigid insulation," which may be plastic foam, rigid mineral wool board, or rigid fiberglass board.
- One-part spray foam sealant appears common when air sealing measures are applied (both fire block and window/door versions).
- Duct mastic appears common when air duct sealing measures are applied.

Some programs or implementers have specifications for the types of materials that may be used, including chemical content.

10 Richard Heath & Associates, Energy Savings Assistance Program: California Installation Standards, August 2019.

11 According to our previous analysis, polyisocyanurate would not be a preferred material from a healthier materials perspective unless it is halogen free. Mineral wool batts would not be a preferred material unless they are formaldehyde free. Residential fiberglass batt insulation made in the United States and Canada is all now formaldehyde free.

12 A wide range of approved materials are listed, including some that would not be preferred from a healthier materials perspective according to our previous analysis.

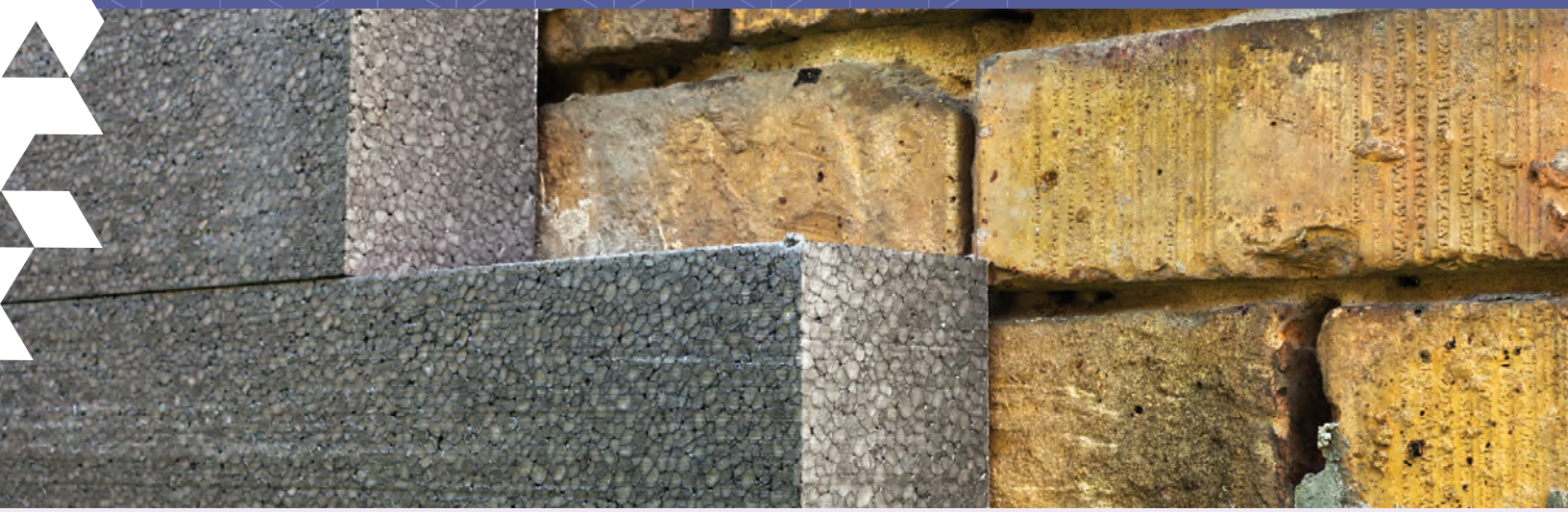
13 According to our previous analysis, blown cellulose, blown fiberglass, and unfaced fiberglass batt insulation are preferred from a healthier materials perspective.

Technical Considerations

Interviewees reported that insulation and air-sealing upgrade measures can lead to a better-performing building enclosure. This can result in indoor environmental quality benefits and more accurate sizing of HVAC equipment, thus reducing the operational cost of the building. However, there are multiple technical challenges to including building enclosure insulation and air sealing in multifamily upgrades.

- Aside from attic insulation, building enclosure insulation, applied from either the interior or the exterior, is not common in low-income multifamily EE upgrades.
    - To apply insulation from the interior, units generally need to be unoccupied. Applying insulation from the interior on a per-unit basis can be done in an occupied building in some cases (depending on the construction) but needs to be sequenced to be done when units are unoccupied. Generally contractors prefer to do a large portion of a building's units at once, such as during a major rehab project. This also avoids disrupting other occupants.
    - Applying exterior insulation can avoid the need for units to be unoccupied but may not be possible, depending on the building facade's ability to handle the additional weight.
- Proper air sealing, including windows, outlets, etc., requires access to the interiors of individual units and can be intrusive to occupants.
- To achieve efficiency and other benefits and to avoid disrupting a building's air flow, air sealing generally needs to be completed for an entire multifamily building. Air-sealing an individual unit alone is not likely to provide much benefit.
- Software programs used to calculate energy savings for allowable measures and to determine rebates, credits, etc., do not accurately capture the expected energy savings from air-sealing measures in multifamily buildings.

Challenges and Opportunities



In this section, we discuss some of the main challenges and opportunities relating to the use of healthier insulation and air-sealing materials in multifamily EE projects. We also discuss issues related to data collection and reporting and the implications for efforts seeking to scale up the adoption of healthier EE solutions.

Challenges

Program design and lack of incentives for implementation

Many of the programs that we researched did not allow or adequately support the implementation of HVAC and/or building enclosure insulation and air-sealing measures. One possible explanation is that due to a combination of the issues outlined in the technical considerations section above, the costs of incentivizing air sealing and insulation in low-income multifamily EE upgrades may seem relatively high. Thus these measures may face challenges in passing required cost-effectiveness tests, which compare the value of expected energy savings with the costs of measures. For customer-funded programs, low-income initiatives generally do not have to be cost effective, but the overall portfolio of programs does, making measures with low cost effectiveness difficult to implement.

Weak program technical specifications

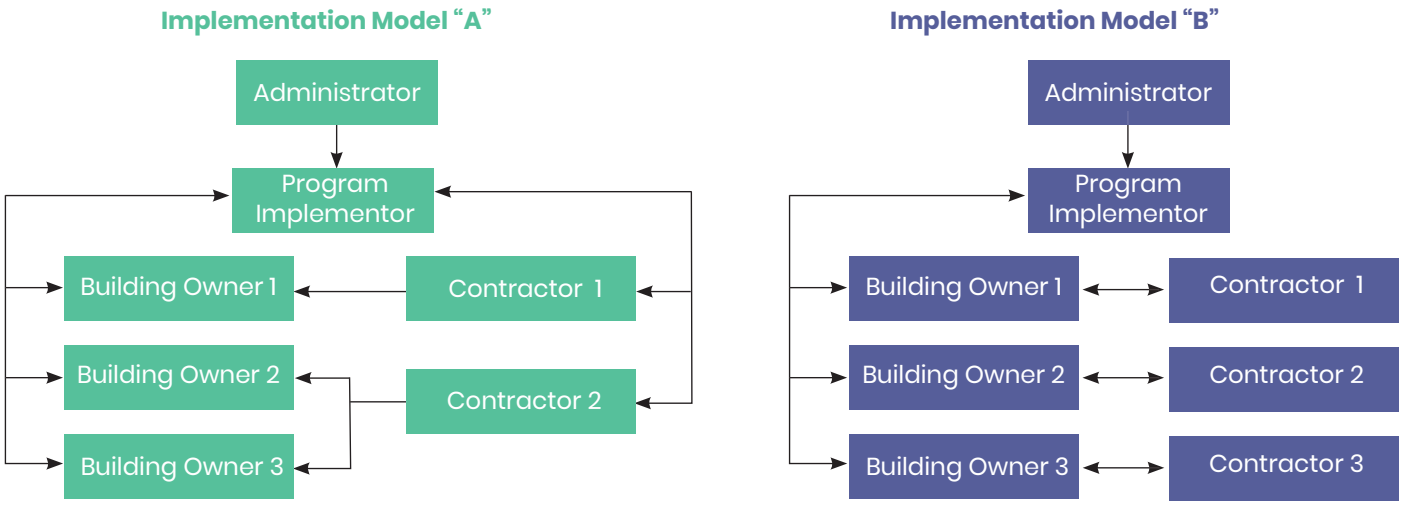
For energy efficiency programs that allow or require the installation of insulation and air sealants, program specifications typically go only as far as providing R-value requirements for insulation. In other words, EE programs do not typically specify that hazardous chemicals should be avoided in the materials being installed.

Lack of state-level data collection and report standardization

In order to learn about EE programs, we looked at publicly available documentation, including program design and impact evaluation reports, for 18 programs running throughout 2019 in five states. Only a handful of programs reported on the total number of EE projects implemented or provided some insight about the subset of projects that included the installation of insulation and air sealants. For the most part, reports were limited to providing a general overview of the programs, including qualifying terms and total expected energy savings. None reported on materials used in upgrades.

The lack of standardization in program reporting meant we were unable to determine the size of investment in insulation and air-sealing measures or materials used across different programs or different states.

Figure 2. Two example models of energy efficiency program implementation.



Fragmented nature of implementation

Where basic mechanisms could be set in place to improve EE program reporting at the state level, reporting quality will likely still suffer due to the disjointed nature of program implementation and the lack of a framework for data collection at the ground level.

Figure 2 shows two models of EE program implementation as examples. There are a number of additional possible structures.[14] In both example models, utilities administrators hire program implementers to lead the implementation of their EE programs. In model A, the program implementer hires contractors to execute the portfolio of EE projects and also interacts directly with building owners. In model B, the program implementer interacts only with building owners and not with contractors. The owners are the ones responsible for hiring contractors to install the EE measures. In some cases, the building owners have the option to choose their own contractors or work with the contractors suggested by the program implementer.

Regardless of the model that is adopted, contractors are often not directed or incentivized to collect and report data about the types of materials used. As a result, this information is often lost or, at the very least, not easily accessible to program implementers. Model B, however, creates a more significant gap between program implementers and information about the materials that are used.

Even if implementers have strong goals for healthier materials, fragmentation of program implementation limits their ability to influence the materials actually used by the contractors.

Opportunities and Recommendations

Improved EE program specifications

Perhaps the most significant opportunity to increase the use of healthier materials in EE programs is through improved program technical specifications that avoid hazardous chemicals. A list of practical recommendations for evaluating, selecting, and writing specifications for healthier insulation and air-sealing materials is available in a report developed by HBN, *Guidance for Specifying Healthier Insulation and Air-Sealing Materials*.[15]

So-called qualified allocation plans in many states and cities already require compliance with building

14 Kate Tanabe, "An Overview of Affordable Multifamily Programs: Best Practices and Context for Utilities," American Council for an Energy-Efficient Economy, September 15, 2021, https://www.aceee.org/topic-brief/2021/09/overview-affordable-multifamily-programs-best-practices-and-context-utilities.

15 Energy Efficiency for All, *Guidance for Specifying Healthier Insulation and Air-Sealing Materials*, February 2019, https://assets.ctfassets.net/ntcn17ss1ow9/6lpUnRB2ABFvoBHtlhA7aY/fe4ccd5a4634c703495e33b811a411a1/NRDC-3094_Specifying_Healhier_Materials_report_05.pdf.

Standardized reporting guidelines for all EE programs can facilitate the development of policy and strategies to increase the use of healthier materials.

certification programs that may include material health criteria. For example, New York City requires developers of affordable housing to comply with the Enterprise Green Communities Criteria. Under these guidelines, developers must avoid formaldehyde-based insulation and are incentivized to avoid two-part spray polyurethane foam and board insulation with halogenated flame retardants. EE programs can further align energy efficiency goals with those for human and environmental health by strengthening existing program specifications or demanding compliance with the materials criteria outlined by green building certifications with strong material health mandates, like Enterprise Green Communities. The latter option has the benefit of not requiring new specification development by individual EE programs. Advocacy to strengthen safer materials criteria more broadly in green building certifications is also needed.

Report standardization

Standardized reporting guidelines for all EE programs can facilitate the development of policy and strategies to increase the use of healthier materials. Under such guidelines, data could shed light on the state of investment (or disinvestment) in particular strategies and the materials most commonly used in EE improvements. Also, standardized reporting would allow a comparison of the health, environmental, and financial performance of different programs, thus providing insight into the factors influencing the success or failure of these initiatives.

Improved data collection

Standardized reporting will create a need for a common data collection framework. Understanding what data need to be collected, the timing of data collection, and the role that different stakeholders can play in this process is essential. This points to the need to build consensus among policymakers, utilities, program implementers, and contractors around reporting goals, resources needed, and practicalities for implementation, among other issues.

Data that can support the use of safer materials include the type and amount (i.e., square footage) of each measure installed, the insulation and air-sealing materials used, and resulting total energy savings. Data that can support implementation of HVAC and building enclosure insulation and air-sealing measures include information on building energy use and indoor environmental quality in units before and after installation of such upgrades.

Updating of EE program structures to robustly incentivize HVAC and building enclosure insulation and air sealing in multifamily buildings

More research is needed into the strengths and limitations of current cost-effectiveness analysis methodologies in relation to HVAC and building enclosure insulation and air-sealing measures for multifamily buildings. This could shed light on opportunities for implementing these measures in projects where technical and financial conditions are currently deemed unviable. For example, accounting for co-benefits like improved indoor environmental quality could offset higher costs. Further, cost-effectiveness tests often do not account for the number of people who could benefit from upgrades, which could be significant in a large multifamily building.

More research and analysis around building enclosure insulation and air sealing in multifamily buildings

Research on the benefits of HVAC and building enclosure insulation and air sealing as EE measures in existing buildings has focused mostly on single-family homes at all income levels. Our interviews with energy efficiency experts suggest that these measures would bring significant benefits in energy savings and improved IEQ to occupants of low-income multifamily buildings. Therefore, it is important that we design low-income multifamily EE programs that include and properly incentivize the implementation of healthy insulation and air-sealing measures and, at the same time, collect information on the benefits (energy savings and co-benefits) resulting from these measures.

Conclusion

There is a large opportunity for low-income multifamily EE programs to make improvements that will better support impactful insulation and air-sealing measures using healthier materials. These changes would benefit building residents through reduced bills and improved indoor environmental quality—and as we saw with the case of removing formaldehyde-based binders from residential fiberglass insulation, using materials without hazardous chemicals will also benefit workers and communities affected by the manufacture, use, and disposal of building materials. Finally, reducing building energy use through effective energy efficiency measures will reduce climate-warming emissions to the benefit of communities at large.

Appendix 1. Materials Survey

This information is being collected for a research project on insulation and air sealing materials used in energy efficiency upgrades being conducted by NRDC and Healthy Building Network for Energy Efficiency for All. All responses are confidential and will only be used in aggregate.

PLEASE FILL OUT YOUR CONTACT INFORMATION AND NUMBER OF PROJECTS COMPLETED IN 2019 FOR [IMPLEMENTER].

IN TABLE 1 AND TABLE 2, PLEASE INDICATE THE INSULATION AND AIR SEALING MATERIALS USED FOR PROJECTS COMPLETED FOR [IMPLEMENTER].

IF YOU DO NOT ADDRESS A PARTICULAR APPLICATION IN THESE PROJECTS, LEAVE THAT ROW BLANK. IF MORE THAN ONE MATERIAL IS USED FOR A PARTICULAR APPLICATION, PLEASE ADD ANOTHER ROW FOR THE ADDITIONAL MATERIAL(S).

Please return the completed survey to [Contact Email Address] by [Date]. Thanks for your participation!

ORGANIZATION

RESPONDENT(S) NAME

EMAIL

PHONE

PROJECTS COMPLETED IN 2019 FOR [PROGRAM IMPLEMENTER] (PROGRAMS INCLUDE: [LIST OF PROGRAMS])

NUMBER OF PROJECTS

SQUARE FOOTAGE ADDRESSED

TABLE 1: INSULATION				
Application product is used for	**Product brand**	**Product name**	**In approximately what percentage of projects completed in 2019 (for [Implementer]) did you use these materials for this application?**	**Units of product purchased or applied in 2019 (for projects for [Implementer])**
ex. Attic floors (open cavity)	ex. Owens Corning	ex. Kraft-Faced EcoTouch PINK Fiberglas Insulation	ex. used in 100% of projects in 2019	ex. 300 packages of 32 sq. ft. each
ex. HVAC ducts	ex. Certainteed	ex. FSK-Faced SoftTouch Duct Wrap	ex. used in 75% of projects in 2019	ex. 150 units of 3" x 48" x 50'
Attic floors (open cavity)				
Attic floors (closed cavity)				
Attic hatch				
Conditioned attic—ceiling				
Conditioned attic—knee walls				
Conditioned attic—collar ties				
Cathedral ceiling				
Roof insulation (exterior)				
Enclosed walls				
Open wall cavities				
Wall insulation (exterior)				
Basement ceiling				
Floor above crawl space				
Foundation wall (interior)				
Foundation wall (exterior)				
Around windows/doors				
HVAC ducts				
HVAC refrigerant line				
Water pipes				
Water heater				
Other—if we missed any specific applications, please add them				

TABLE 2: AIR SEALING				
Application product is used for	**Product brand**	**Product name**	**In approximately what percentage of projects completed in 2019 (for [Implementer]) did you use these materials for this application?**	**Units of product purchased or applied in 2019 (for projects for [Implementer])**
ex. Air ducts	ex. Hardcast	ex. Versa-Grip 181	ex. used in 75% of projects in 2019	ex. 50 one-gallon buckets
ex. Window/door sealing (exterior)	ex. Henry Company	ex. 925 - BES Sealant - White	ex. used in 25% of projects in 2019	ex. 100 10.1-oz. tubes
Air ducts				
Window/door sealing (interior)				
Window/door sealing (exterior)				
Trim (interior)				
Trim (exterior)				
Unconditioned roof cavity				
Conditioned attic—ceiling				
Conditioned attic—knee walls				
Conditioned attic—collar ties				
Foundation air sealing				
Plumbing/electrical/HVAC penetrations				
Miscellaneous other penetrations				
Top/bottom of wall plates				
Other—if we missed any specific applications, please add them				

Appendix 2. Energy Efficiency Programs Reviewed

Sources include publicly available documents or conversations with involved parties about the size of the programs and the portion of projects that included insulation and air-sealing measures. "*Not found*" indicates either that we were not able to find a report for the projects or measures implemented in 2019 or that the report lacked information about the specific number of projects or measures installed. The research team acknowledges that some reports may have been missed due to limitations related to the search syntax used (e.g., [program name] + [state] + [2019 annual report]).

Administrator	Program	Multi-family criteria	Affordable criteria	Allowable insulation and air-sealing measures	Implementer	Total projects (2019)	Information on insulation and air-sealing measures installed (2019)
California							
Department of Community Services and Development	Low-Income Weatherization Program for Multifamily Properties (LIWP-MF)	Building contains at least 5 units	At least 66 percent of households are at or below 80% of Area Median Income	Required measure: in-unit duct sealing In general, all measures that result in greenhouse gas reductions are eligible Insulation: attic, roof, wall, floor, pipe, duct Air sealing: building shell (roof cavity, crawl space, windows, attic hatch, etc.), air ducts[16]	AEA	*Not found*	Air sealing and insulation included in 15 projects[17]
San Diego Gas and Electric	Energy Savings Assistance Common Area Measures (ESA CAM)	Building contains at least 5 units	Minimum of two-thirds of residents meet ESA income requirements	Insulation: attic, wall[18]	Willdan	6	*Not found*
Pacific Gas and Electric					TRC Solutions	0	
Southern California Edison					In-house	1	
Southern California Gas Company					In-house	3	

16 Association for Energy Affordability (AEA), "Low-Income Weatherization Program for Multifamily (LIWP-MF)," PowerPoint presentation, https://camultifamilyenergyefficiencydotorg.files.wordpress.com/2020/07/liwp-mf_programslides_mar2020.pdf (accessed October 18, 2021).

17 Megan Ching, program manager, AEA, personal communication via email, October 9, 2020.

18 ESA Program, "Energy Savings Assistance Common Area Measures," https://esacommonarea.com/wp-content/uploads/2019/09/ESACAM_EligibleMeasuresList.pdf (accessed Oct 18, 2021).

Administrator	Program	Multi-family criteria	Affordable criteria	Allowable insulation and air-sealing measures	Implementer	Total projects (2019)	Information on insulation and air-sealing measures installed (2019)
Illinois							
ComEd	Income Eligible Multifamily Savings Program	Building contains at least 3 units	Based on eligible census tract, subsidy status, or rent level	Eligible measures not specified beyond "insulation and air sealing"[19] In response to our survey, contractors reported completing a wide variety of measures: Insulation: attic, roof, wall, duct, pipe Air sealing: duct, window, door, trim, roof, attic, foundation, penetrations	Elevate	673	Insulation = 573,803 sq. ft. Air sealing = 168,186 LF. Pipe Insulation = 41,609 LF.
People's Gas & North Shore Gas						327	Air sealing = 47,966 LF. Attic insulation = 129,696 sq. ft. Pipe insulation = 39,447 LF. Foundation sidewall insulation = 1,304 sq. ft.
ComEd, People's Gas, Northshore Gas	Public Housing Energy Savings Program	*Not found*	Limited to public housing authorities	Eligible measures not specified beyond "insulation and air sealing"[20]	Elevate	140	Envelope insulation = 183,651 Sq. Ft.
Nicor Gas	Multifamily Income Qualified Program	Building contains at least 5 units	Households with a combined income at or below 150 percent of the federal poverty level using state and HHS funds, and those at or below 200 percent of the federal poverty level using DOE funding	In collaboration with the Illinois Home Weatherization Assistance Program (IHWAP); eligible measures not specified beyond "insulation and air sealing." Program report identifies the following measures installed in 2019: Insulation: attic, basement sidewall, duct, pipe Air sealing: building shell, duct[21]	Anura	9,022 (includes IHWAP and energy-saving kits)	Air sealing = 190,623 LF. Attic insulation = 83,162 sq. ft. Basement sidewall insulation = 4,272 sq. ft. Pipe insulation = 52 LF.

19 ComEd, "Multi-Family Energy Upgrades," https://www.comed.com/WaysToSave/ForYourHome/Pages/MultiFamilyEnergyUpgrades.aspx (accessed October 18, 2021).

20 ComEd, "Energy Savings for Public Housing Authorities," https://www.comed.com/WaysToSave/ForYourHome/Pages/publichousing.aspx (accessed October 18, 2021).

21 Sophie Gunderson et al., "Income Qualified Multi-Family Program Impact Evaluation Report," Guidehouse, June 5, 2020, https://ilsag.s3.amazonaws.com/Nicor-Gas-IQ-MF-2019-Impact-Evaluation-Report-2020-06-05-Final.pdf.

Administrator	Program	Multi-family criteria	Affordable criteria	Allowable insulation and air-sealing measures	Implementer	Total projects (2019)	Information on insulation and air-sealing measures installed (2019)
Illinois							
Ameren Illinois Company (AIC)	Income Qualified Multifamily	Building contains at least 3 units	Multifamily properties with the majority of tenants receiving state, federal, or other income-qualified assistance	Insulation: attic Air sealing: attic, in-unit weatherization[22]	Leidos	49, of which 28 were direct installation	No properties received building envelope measures, although air sealing and attic insulation were eligible initiative measures
	Public Housing Program	*Not found*	Multifamily properties owned by government entities Serves properties with an average household income at or below 300 percent of federal poverty guidelines that are owned or managed by public housing authorities (PHAs)	Insulation: attic Air sealing: attic, in-unit weatherization[23]		151	Air sealing = 76 measures in 28 properties Attic insulation = 78 measures in 30 properties
Louisiana							
Entergy New Orleans	Energy Smart Multifamily (Multifamily Solutions)	Building contains at least 5 units		Program report identifies the following measures installed in 2019: Insulation (unspecified) Air sealing: general, duct[24]	Aptim and Green Coast Enterprises		Measures installed: Air sealing = 37 Duct sealing = 246 Insulation = 6
	Energy Smart Low-Income (Income Qualified Weatherization)	Building contains up to 4 units	Income below 200 percent of the federal poverty level	Insulation: attic, pipe Air sealing: general, duct[25]	Aptim and Franklin		Measures installed: Air sealing = 28 Duct sealing = 386 Insulation = 80

22 Ameren Illinois, "Multifamily Property Owner," https://amerenillinoissavings.com/multifamily/multifamily-property-owners/ (accessed Oct 18, 2021).

23 Ibid.

24 Energy Smart, *Annual Report, Program Year 9*, July 31, 2020, https://www.all4energy.org/uploads/1/0/5/6/105637723/2020_07_31_ud-08-02___ud-17-03_eno_energy_smart_py9_annual_rpt__final_.pdf.

25 Entergy, "Income Qualified Weatherization," https://www.entergy-louisiana.com/your_home/save_money/ee/iq/ (accessed October 18, 2021).

Administrator	Program	Multi-family criteria	Affordable criteria	Allowable insulation and air-sealing measures	Implementer	Total projects (2019)	Information on insulation and air-sealing measures installed (2019)
Minnesota							
Xcel Energy	Multi-Family Energy Savings ELECTRIC	Building contains at least 5 units	*Not found*	*Not found*	Franklin Energy Services	1,766	*Not found*
Xcel Energy & Centerpoint Energy	Multi-Family Building Efficiency (MFBE)	Building contains at least 5 units	*Not found*	*Not found*	Energy Insight	831	*Not found*
CenterPoint	Low-Income Multi-Family (LIMF) Housing Rebates	Building contains at least 5 units	Must have a minimum of 66% units occupied by low-income households, demonstrated as follows: Buildings prequalified for the U.S. Department of Energy Weatherization Assistance Program (WAP) are automatically eligible. Buildings certified for the Minnesota Low-Income Rental Classification (LIRC) are automatically eligible. Restrictions or mortgage covenants, which restrict a minimum of 66 percent of housing units to low-income households, can be used to demonstrate eligibility. Other means of demonstrating eligibility, including (but not limited to) participation in the project-based Section 8 voucher program, may be acceptable.	*Not found*	CenterPoint	690	Air sealing and insulation = 258 projects
MERC	Multifamily Direct Install Plus (MFDI)	Building contains at least 5 units	*Not found*	Insulation: attic, roof, sidewall; for buildings larger than 20 units, typically only attic[26]	Center for Energy and Environment (CEE)	*Not found*	*Not found*

26 Lisa Rafferty, managing director, Applied Energy Group, personal communication via email, February 23, 2021.

Administrator	Program	Multi-family criteria	Affordable criteria	Allowable insulation and air-sealing measures	Implementer	Total projects (2019)	Information on insulation and air-sealing measures installed (2019)
Missouri							
Ameren	Community-Savers (Multifamily Low-Income program)	Building contains at least 3 units	At least 51 percent of units must be federally subsidized or occupied by households with incomes at or below 200 percent of the federal poverty level. Properties where fewer than 51 percent of units qualify may participate in the program if the owner/manager verifies installation of comparable qualified energy efficiency measures at his or her own expense in all non-qualifying units	Insulation: pipe, HVAC duct, metal roof/wall[27]	ICF ICAST	*Not found*	*Not found*
Spire (formerly Laclede Gas)	Community-Savers (aka Income Eligible MF)	Building contains at least 3 units	Participation in a federal, state, or local subsidized housing program Location in a census tract identified as low-income, based on HUD's annually published Qualified Census Tracts as a starting point Proof of residents' gross annual income at or below 80% of the area median income	*Not found*	ICAST, ICF, in-house	*Not found*	*Not found*

27 Ravi Malhotra, founder and president, ICAST, personal communication via email, February 15, 2021.

Administrator	Program	Multi-family criteria	Affordable criteria	Allowable insulation and air-sealing measures	Implementer	Total projects (2019)	Information on insulation and air-sealing measures installed (2019)
Missouri							
Ameren	Ameren Gas—Multifamily MEEIA program	*Not found*	Participation in a federal, state, or local subsidized housing program Proof of resident income levels at or below 80 percent of area median income or 200 percent of federal poverty level Building is within a census tract included on the company's list of eligible low-income census tracts Where a property does not meet one of the income eligibility criteria listed above but has both qualifying and non-qualifying tenants, at least 50 percent of tenants must be eligible in order to qualify the entire property	*Not found*	ICAST	*Not found*	*Not found*
	Ameren Gas—Multifamily Wx pilot	*Not found*	*Not found*	*Not found*	CAAs	*Not found*	*Not found*
Evergy (formerly KCP&L)	Income-Eligible Multi-Family (IEMF)	*Not found*	At least 50 percent of units are rented to households at or below 200 percent of the federal poverty level, or at or below 80 percent of area median income.	*Not found*	ICF	*Not found*	*Not found*

Appendix 3. Findings Related to EE Upgrades With Funding Through the Low-Income Housing Tax Credit (LIHTC)

As part of this project, we aimed to understand the approximate number of upgrades done through state tax credit programs that include insulation and/or air-sealing measures and how this compares with those measures performed though EE programs. We reviewed the U.S. Department of Housing and Urban Development (HUD) LIHTC database for publicly available information.[28] We also spoke with representatives from a state housing finance agency and housing and energy efficiency advocates experienced with LIHTC in order to understand what data are currently tracked.

Table A1. Estimated LIHTC-funded rehabs that could have included insulation and/or air sealing based on information from the HUD LIHTC database.

State	2017	2018
California	39	6
District of Columbia	4	4
Georgia	10	10
Illinois	2	8
Louisiana	0	0
Maryland	28	15
Michigan	14	1
Minnesota	14	4
Missouri	10	6
New York	13	6
North Carolina	5	1
Pennsylvania	6	0
Virginia	17	16
Total projects put in service	**162**	**77**

Findings on data collection, reporting, and transparency:

- The HUD LIHTC database includes a range of information about projects.[29] However, it does not indicate what type of work was completed, such as whether insulation or air sealing was part of the work.

28 U.S. Department of Housing and Urban Development (HUD), "LIHTC Database Access," https://lihtc.huduser.gov/ (accessed October 26, 2021).

29 Ibid.

30 At the time of this research, data were available in the HUD database for projects placed in service through 2018. To determine an approximate maximum expected number of LIHTC-funded projects that were rehabs that may have included insulation and/or air sealing, we filtered for EEFA states (California, District of Columbia, Georgia, Illinois, Louisiana, Maryland, Michigan, Minnesota, Missouri, New York, North Carolina, Pennsylvania, and Virginia); type = acquisition and rehab, both new construction and A/R, existing, or not indicated; year put in service, 2017 or 2018. Projects that did not include a year put in service were not counted.

- The estimated maximum number of LIHTC-funded rehabs that could have included insulation and/or air-sealing is shown in Table A1.[30]
    - From the data that are available for EE programs and LIHTC projects, it is unclear how the share of LIHTC-funded rehabs with insulation and/or air sealing compares with the share of projects with insulation and/or air sealing completed though EE programs. These numbers may also vary from state to state.
- Housing finance agencies (HFAs) do not typically have or cannot share information that would provide more details on the scope of work and materials used, such as project specifications.

State observations from two example states:

- Minnesota
    - Most LIHTC-funded projects are expected to be new construction or adaptive reuse.
    - Other state funding sources besides LIHTC could also go to rehab projects.
    - New insulation is not common in rehab projects, with the exception of blown cellulose in attics.
    - Air sealing is required only in certain situations, based on existing attic insulation R-value and heating source.
- California
    - Often LIWP funding is leveraged at the same time as funding from the California Tax Credit Allocation Committee (TCAC), California's LIHTC program.
    - LIHTC projects, including rehabs, are required to comply with the CalGreen Standard. This includes minimal material health requirements for air-sealing materials.[31]

31 CalGreen requires that sealants meet the South Coast Air Quality Management District (SCAQMD) Rule 1168, which places limits on volatile organic compounds (VOCs) and prohibits a handful of hazardous compounds (chloroform, ethylene dichloride, methylene chloride, perchloroethylene, and trichloroethylene).

Appendix 4. AEA Technical Specifications

Insulation: Attic Insulation

Energy savings for this measure assumes that R-38 insulation is installed in the attic cavity to QII (Quality Insulation Installation) and that all accessible air leakage bypasses are sealed with an air barrier.

Materials: Blown Insulation

- Material: Type 1 cellulose loose-fill insulation in accordance with ASTM C 739 *or* Type 1 mineral fiber loose-fill insulation in accordance with ASTM CC764
- Fire testing: Meets ASTM E 84
- Environmental characteristics: Acceptable fungi resistance and corrosiveness
- Formaldehyde free
- Thermal resistance: Must be installed to minimum settled thickness specified by manufacturer to achieve minimum R-values required above

Material: Fiberglass Batt Insulation

- Material: FSK (Foil Scrim Kraft) faced for application over exposed vertical walls, unfaced for application in exposed vertical wall cavities. Both types will be in accordance with ASTM C 764
- Fire testing: Meets ASTM E 84
- Environmental characteristics: Acceptable fungi resistance and corrosiveness
- Formaldehyde free
- Thermal resistance: Must be installed to minimum thickness specified by manufacturer to achieve minimum R-value required above

Material Coverage Charts: Each manufacturer has specific coverage charts, which must be referenced to ensure the minimum settled thickness is installed.

Delivery, Storage and Handling: All material must be new. Materials shall be delivered to the site in clearly labeled packaging. Materials shall be protected from the weather and other damage. Damaged materials found unsuitable for use will be rejected and shall be removed from the site. Insulation materials shall not be installed under temperature and humidity conditions not approved by the manufacturer.

Pre-inspection: An inspection will be conducted prior to air sealing and insulating to verify that no existing water leaks, damage, or other durability issues exist. Any issues found will be immediately notified to owner's authorized representative and resolved prior to installation.

Electrical: Where knob and tube wiring exists, a licensed electrical contractor will inspect and certify wiring to be safe and place a warning at all entries to the attic about the presence of knob and tube wiring, or will replace knob and tube wiring with new, appropriate wiring in accordance with local codes. All electrical boxes will be flagged to be seen above the level of the insulation. Open electrical junctions will have covers installed.

Air Sealing: All readily accessible areas where heated air can bypass the insulation shall be sealed to prevent the transfer of air using appropriate air barrier materials (foam, caulking, sheet metal, etc.). These areas include around furnace flues, exhaust air ductwork, piping and wiring penetrations, open framing cavities, and sections of the ceiling that currently do not have installed insulation.

Attic Accesses: When located between the air and thermal boundary of the attic and conditioned space, these shall be insulated to same R-value as final insulated assembly and will be weather-stripped.

Preparation: Concurrent with air sealing, contractor shall ensure that existing batt insulation is in full contact with the attic ceiling (no air space voids) prior to installing blown insulation.

Distance to Combustibles: Insulation may not be installed within 3 inches of any heat sources (chimneys, flues, non-IC-rated fixtures/fans) and shall be baffled to a minimum of 6 inches above installed level of insulation. Bypass sealing materials used for these areas must be nonflammable (e.g., metal flashing sealed with high-temperature caulking, etc.). Light fixtures/fans/heater units, if not IC rated, shall be baffled or covered with a sealed sheetrock box constructed with manufacturer's specified minimum clearances between fan and box to allow heat dissipation.

Attic Baffles: All soffit and eave venting will be baffled prior to insulation application to allow for ventilation to remain unobstructed (minimum 2 inches of air space required across width of framing bay). Baffle will extend from outside of exterior top plate to a minimum of 6 inches above installed level of insulation, allowing insulation to cover exterior top plate. Baffles must be of rigid construction (paper, plastic, foam, plywood, etc.). Fiberglass batts will not be used as a means of baffling. Where combustion air vents are open to attic, vents shall be baffled to a minimum of 6 inches above installed level of insulation. Attic access doors/hatches shall be baffled to a minimum of 6 inches above installed level of insulation.

Insulation Rulers: The contractor shall affix thickness rulers labeled in inches or R-values to trusses with at least one marker per 300 square feet throughout the attic area, with measurement beginning at the air barrier. Each marker shall face the attic access.

On-Site Documentation: A signed and dated attic card will be provided that includes: insulation type, installed thickness and settled thickness, coverage area, R-value, number of bags installed in accordance with manufacturer's specifications.

Insulation: Floor Cavity Insulation

Savings for this measure assume that R-19 insulation is in the floor cavity to a minimum level of R-19 and that all accessible air leakage bypasses are sealed.

Materials: Fiberglass Batt Insulation

- Un-faced fiberglass batt insulation
- Fire testing: Meets ASTM E 84
- Environmental characteristics: Acceptable fungi resistance and corrosiveness
- Formaldehyde free
- Thermal resistance: Must be installed to minimum settled thickness specified by manufacturer to achieve minimum R-values required above

Installation: Insulation shall be installed in full contact with subfloor without gaps, voids, compressions, or misalignments. Insulation will be installed to prescribed R-value of R-19. Batts shall be securely fastened with physical fasteners such as permanent rods or netting. These fasteners must ensure that insulation remains in contact with subfloor. A minimum of 36 inches spacing between fasteners is required. Compression fit alone does not meet these minimum requirements. Batts shall be spliced cleanly and separated as necessary to allow for the passage of wiring/plumbing/framing/etc. to ensure the batt is not compressed and does not leave any voids or gaps.

Contractor Pre-inspection: Prior to installation, recommend having appropriate tradesperson inspect the crawl space prior to air sealing and insulating to verify that no existing water leaks, damage, or other durability issues exist. Any issues found must be immediately notified to owner's authorized representative and resolved prior to installation.

Electrical: Where knob and tube wiring exists, a licensed electrical contractor will inspect and certify wiring to be safe and place a warning at all entries to the attic about the presence of knob and tube wiring, or will replace knob and tube wiring with new, appropriate wiring in accordance with local codes. The electrician will provide a C-10 inspection report to the owner and program certifying the system is safe to cover.

Air Sealing: All readily accessible areas where heated air can bypass the insulation shall be sealed to prevent the transfer of air using appropriate air barrier materials for the assembly being sealed (foam, caulking, sheet metal, etc.).

HVAC: Seal and Clean All Accessible Ducting

If ducted HVAC is to remain and will use the existing ductwork, it must be professionally and thoroughly cleaned. Savings for this measure assume that all accessible sections of the ductwork including all boots, registers, plenums, exposed ductwork, and equipment are to be sealed using water-based duct mastic and tested to confirm total duct leakage is less than 15 percent of the new air handler cooling flow rate.

Materials: Low-VOC water-based duct mastic, fiberglass mesh, and tapes per application requirements below.

Final Leakage: All forced air duct systems will be tested per the 2013 CEC Residential Appendices RA3.1.4.3.1 standard under 25 pascals using a duct blaster with a final total duct leakage rate of less than 15 percent of furnace fan flow rate in cubic feet per minute (CFM). Furnace fan flow CFM rate will be calculated as the sum of 21.7 × (furnace output Btu/1,000). Testing results will be documented and reported to the program representative via a CEC-CF2R-MCH-20-H or CEC-CF3R-MCH-20-H for each unit tested.

For systems that will still contain asbestos after remediation and cannot be pressure tested, those systems must pass a visual verification by program staff prior to duct insulation installation proving that all accessible leakage locations were sealed.

Sealing Locations: The following locations will be sealed:

- Seams, cracks, joints, holes, and penetrations less than ¼ inch will be sealed using fiberglass mesh and mastic. Mastic alone will be acceptable for holes less than ¼ inch that are more than 10 feet from air handler.
- Seams, cracks, joints, holes, and penetrations between ¼ and ¾ inch will be sealed in two stages: (1) They will be backed using temporary tape (e.g., foil tape) as a support prior to sealing. (2) They will be sealed using fiberglass mesh and mastic. Fiberglass mesh and mastic will overlap temporary tape by at least 1 inch on all sides. Fiberglass mesh and mastic will become the primary seal.
- Seams, cracks, joints, holes, and penetrations larger than ¾ inch will be repaired using rigid duct material. Mastic will overlap repair joint by at least 1 inch on all sides.
- Behind registers/return grill: Gaps between duct supply and return gypsum less than ¼ inch will be sealed using mastic or appropriate flexible caulking. Gypsum edge will be wetted before applying mastic.

- At furnace: Joints will be sealed, and cracks/holes not needed for proper function of air handler will be sealed using removable sealant (e.g., foil tape).
- In return plenum: Debris and dirt will be cleaned out of the return platform. Backing or infill will be provided as needed to meet the specific characteristics of the selected material and the characteristics of the open space to create a leak-free assembly. Material will be rated for use in return duct systems.

Return Filter: After cleaning and sealing, furnace filter will be replaced with new, properly sized filter of rating/type used by maintenance staff at building.

System Operation: After sealing, proper system operation will be confirmed by contractor to ensure furnace operates within manufacturer's static pressure and temperature rise requirements, and that system noise levels are acceptable.

Documentation, Mid-construction: Contractor to provide evidence of professional duct cleaning (typically before and after photos of interior of ductwork are provided by cleaning contractor). LIWP program to inspect first building duct system after sealing but before drywall repair to confirm all accessible leakage locations have been sealed.

Documentation, Post-construction: Contractor to hire third-party Home Energy Rating System (HERS) rater to test duct leakage as required by code. Testing results will be submitted to LIWP for verification.