Decarbonizing Homes

Improving Health in Low-Income Communities through Beneficial Electrification

Report / Oct 2021

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About Us

About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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Executive Summary

Executive Summary

Beneficial electrification of housing—building tight, well-ventilated buildings with all-electric appliances and equipment—can improve health equity in low-income communities while achieving specific goals such as healthy indoor environments, emissions reductions, and cost savings.

Beneficial electrification reduces harmful exposure within the home to indoor allergens and pollutants, including those produced by fossil fuel combustion, and reduces vulnerabilities related to energy insecurity and inaccessibility to air conditioning. Achieving these health benefits requires a holistic approach to building electrification that considers housing quality and energy insecurity alongside reductions in greenhouse gas emissions.

This report bridges the gaps among several areas of professional practice—public health, housing policy, building science, and utility regulation—to show how policies for beneficial electrification can be oriented to deliver health benefits for the most vulnerable residents.[i]

Part 1 identifies the **health improvements that may accompany beneficial electrification** by examining recent research on the health harms of fossil fuel combustion, poor indoor environmental quality, extreme heat, and energy insecurity.

Part 2 examines **how beneficial electrification may improve health in low-income communities by reducing harmful exposures and mitigating vulnerabilities** associated with environmental racism, persistent poverty, and other social determinants of health.

Part 3 offers **near-term policies** for beneficial electrification that improves health.

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[i] While it casts a broad, multidisciplinary net, this report examines those health effects most directly tied to beneficial electrification. It does not address all climate-related health risks, nor does it examine health aspects of housing design and construction, such as designing to encourage physical exercise (active design) or health effects from workplace exposure to the manufacture of building components.

Introduction

Introduction

This report seeks to inform policymakers and advocates in the public health, housing, and energy/utility sectors by surveying the paths by which beneficial electrification of housing can directly and indirectly improve the health of low-income communities.[ii] Its purpose is to expand on prior beneficial electrification frameworks and provide a fact-based foundation for incorporating health equity into building decarbonization efforts. The report also suggests near-term state and local policies to deliver the benefits of beneficial electrification to low-income communities.[iii]

Research has established strong links between housing and health. Because beneficial electrification improves housing quality, it has the potential to serve as a transformative and empowering lever toward a just energy transition.

Beneficial Electrification of Housing

Advances in renewable electric generation have made possible a dramatically cleaner electric grid. Rapid beneficial electrification of transportation, buildings, and industry is now widely considered critical to achieving the deep reductions in greenhouse gas (GHG) emissions necessary to avoid the worst impacts of climate change.

Whereas "electrification" refers to any replacement of fossil fuel end-use equipment and appliances with electric alternatives, "beneficial electrification" typically means doing so in ways that deliver specific benefits.[1] The targeted benefits of electrification can include GHG emissions reductions, lower costs to utility customers, and better management of the electric grid.[2] Originally a utility-sector term, "beneficial electrification" has recently crossed over into more general policymaking discourse.

Making this utility-centric term relevant to the housing sector requires acknowledging that "a well-functioning housing sector is, first and foremost, one that meets housing needs in an efficient, equitable, and sustainable manner, while freeing resources and energies to meet a host of other important needs."[3] Beneficial electrification, as it has been defined outside the housing field, has not fully addressed how moving from fossil fuels to electricity helps to meet housing needs.

Despite this, the electrification of housing end uses affects fundamental aspects of housing quality, such as the provision of heating, cooling, and hot water, as well as cooking. The costs and potential cost savings resulting from changing fossil fuels to electricity also affect housing cost burdens.[iv] Therefore, for the purposes of this report, we propose the following guiding principle for the beneficial electrification of housing:

Beneficial electrification of housing should lower housing cost burdens and improve housing quality to create a safe and healthful indoor environment, while reducing GHGs and improving how buildings interact with the electric grid.

[ii] "Beneficial electrification" first emerged in 1992, when utility-industry researchers defined the term to describe applications of electricity that "reduce primary energy use, decrease CO_2 emissions, and increase productivity." Although it has come to mean replacing fossil fuels with electricity, "electrification" as used in the 1992 report included both new end uses of electricity (e.g., computers) and converting fossil fuel end uses to electric end uses. In 2018, the Regulatory Assistance Project, an independent nongovernmental organization for utility regulators, expanded the criteria of beneficial electrification to fit the goals of regulators by including saving money for customers and enabling better grid management.

[iii] Definitions of "low-income" vary across programs and context, but in general the term can be understood as describing households earning up to 80% of the median income of their local community.

[iv] Housing cost burden is defined as rent or mortgage payments plus the cost of utilities.

Effectively and efficiently meeting thermal and indoor air quality needs through all-electric equipment is also inextricably related to the building enclosure and ventilation system. Beneficial electrification of housing thus entails the combination of:

1. reducing energy load with safe, high-performance building envelopes and safeguarding indoor environmental quality by controlling indoor air movement through air sealing, compartmentalization, and balanced mechanical ventilation;[v]

2. installing highly efficient, all-electric equipment and appliances, such as heating and cooling equipment, domestic hot water heaters, stoves, and clothes dryers, and ensuring adequate electrical service;

3. using demand controls, on-site renewable energy, and energy storage to manage the amount and timing of electric energy consumption.

"Preexisting" housing deficiencies such as structural issues, asbestos, mold, or inadequate wiring must be addressed prior to or in conjunction with moving from fossil fuel equipment to electric equipment.[4] However, resources are often available only to meet immediate needs, and owners may need to pursue aspects of beneficial electrification incrementally.

Beneficial Electrification and Low-Income Communities and Communities of Color

The marginalization and disinvestment in low-income communities and communities of color have yielded stark health disparities. To maximize the inclusion of and benefits to low-income communities, beneficial electrification should address the specific circumstances that these communities face.

A large body of research has definitively linked housing, poverty, and health. Lack of secure housing tenure,[vi] for example, results in poor health by disrupting healthcare access and health management.[5] Home environments have been shown to be important determinants of resident health, especially in low-income populations.[6] Poor-quality housing—which introduces toxic materials (e.g., lead) into homes and poorly manages the movement of air, moisture, water, and pests—causes well-documented adverse effects on childhood development and exacerbates a range of chronic health conditions for residents of all ages.[7]

Historic land use decisions have disproportionately exposed low-income communities and communities of color to high levels of outdoor pollution from both mobile sources (such as truck transport) and stationary sources (such as power plants and polluting industries). These exposures contribute to a variety of health conditions, from asthma to low birth weights to premature mortality.[8] New research now shows that low-income people and people of color are again disproportionately harmed by extreme heat and other manifestations of the climate emergency.[9]

Research has yet to examine beneficial electrification in low-income communities holistically to understand its health impacts. Nevertheless, there is already compelling evidence that beneficial electrification of housing (encompassing envelope and compartmentalization improvements, equipment and appliance replacement, and provision of grid services) delivers health benefits that are particularly important for low-income residents.

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[v] Compartmentalization refers to isolating areas within a building (like individual apartments) from each other, primarily to control air movement. Indoor environmental quality is determined by many factors, including indoor air quality and other health, safety, and comfort issues such as temperature, lighting, acoustics, and moisture/dampness.

[vi] Forms of housing tenure describe the legal structures that govern how people may occupy dwellings and enjoy the property rights and financial benefits associated with occupancy. See **https://shelterforce.org/2016/09/28/a-new-perspective-on-housing-tenure/** for more. Security of tenure describes the degree to which occupants' rights and benefits are protected from infringement. See **https://www.ohchr.org/EN/Issues/Housing/Pages/SecurityOfTenure.aspx**.

A Note on "Beneficial Electrification" and "Equitable Electrification"

Creating opportunities for all people to thrive in safe, sustainable, affordable, and healthy environments contributes to more resilient and equitable communities. In fostering a system that is rooted in inclusion, accountability, anti-oppression, collective care, and joy, decarbonization efforts will require deliberate and inclusive actions. Examining considerations of equity in buildings is an emerging practice and one that calls for a continuous commitment to learning and evolving as a community.

Various definitions exist for both beneficial and equitable electrification.[10] Shared values across both definitions include lowering climate impacts and costs to both utilities and customers. For the purposes of this report, we chose to use the term beneficial electrification, but we have expanded upon previous, utility-centric interpretations to include improving health, safety, and resilience. This expanded view is a step toward equitable electrification. To achieve equitable electrification more fully, additional elements must also be considered, such as protecting against forced displacement, providing additional considerations for renters, and addressing procedural equity, restorative justice, and energy democracy.

Methods

In seeking to understand the health benefits of beneficial electrification for these populations, the authors rely primarily on recent systematic reviews of health studies. The authors found these reviews through PubMed and Google Scholar using the search term "health" with "housing quality," "poverty," "low-income neighborhood," "indoor air quality," "indoor environmental quality," "extreme heat," "energy burden," "energy security," and "combustion." Past reports by RMI were included in the literature review.

The authors also conducted semi-structured interviews with subject matter experts to inform report design, as well as to build on, validate, and complement findings gained from other approaches. Current scholarship on the energy transition reflects the important uncertainties that remain about how it will proceed. Projections related to the energy transition that are cited in this report, therefore, are taken primarily from scientific papers of the national labs supported by the US Department of Energy (DOE).

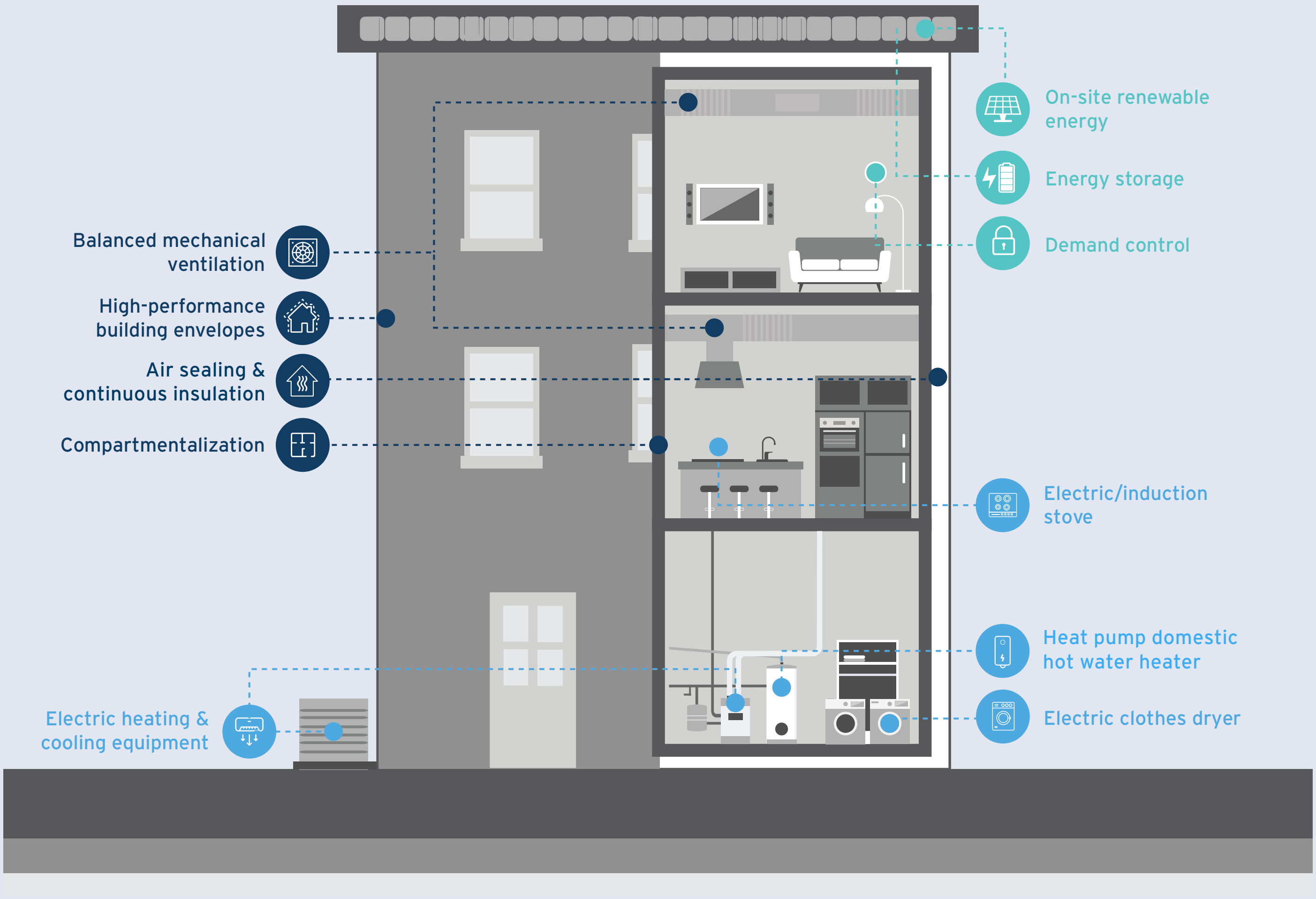
Exhibit 1 Beneficial Electrification of Housing

Beneficial electrification of housing should lower housing cost burdens and improve housing quality to create a safe and healthful indoor environment, while reducing GHGs and improving how buildings interact with the electric grid.

1 Reducing energy load with safe, high-performance building envelopes and safeguarding indoor environmental quality by controlling indoor air movement through air sealing, compartmentalization, and balanced mechanical ventilation

2 Installing highly efficient, all-electric equipment and appliances, such as heating and cooling equipment, domestic hot water heaters, stoves, and clothes dryers, and ensuring adequate electrical service

3 Using demand controls, on-site renewable energy, and energy storage to manage the amount and timing of electric energy consumption



Part 1: How Can Beneficial Electrification Improve Health?

Part 1: How Can Beneficial Electrification Improve Health?

Building tight, well-ventilated buildings with all-electric appliances and equipment will directly improve resident health by reducing indoor allergens and pollutants, including those from the combustion of fossil fuels, and by reducing local outdoor combustion pollutants. All-electric space conditioning equipment can also benefit health by keeping temperature and humidity within safe and comfortable limits. Achieving all of this while reducing housing cost burdens will ameliorate another important driver of health inequity.

Buildings as Integrated Systems

Performance characteristics of the building envelope determine the loads that mechanical systems, including in all-electric buildings, must be designed to meet. (A building's mechanical systems include those for heating, cooling, and ventilation.) It is a recognized best practice to improve envelope performance before sizing the mechanical systems whenever possible. Even when envelope and mechanical system improvements must be phased, they should be considered together as an integrated system when considering costs, GHG emissions, and indoor environmental quality.

The primary function of mechanical systems is to work in tandem with the building envelope to maintain a healthy indoor environment. This includes thermal comfort and indoor air quality. Proper control of air movement in and out of a building through air sealing of the exterior envelope and compartmentalization of the interiors ensures that ventilation systems will work correctly. If the building is not sealed and compartmentalized, the air within the building will move unpredictably (because of factors like stack effect, the airflow caused by warm indoor air rising and escaping), and thus stymie the efforts of the ventilation system. Proper air sealing and insulation and well-designed ventilation in turn enable minimizing the costs and maximizing the environmental benefits of rightsized heating and cooling systems.

Although the implementation of beneficial electrification will differ across buildings, for the purposes of this report we make the following assumptions about the interventions (or, in construction jargon, "scopes of work") that should be included in beneficial electrification packages:

1. Replacing all fossil fuel-burning equipment and appliances with efficient electric alternatives

2. Implementing a high-performance envelope (insulation and air, water, and vapor control) in tandem with mechanical ventilation, performance-tested to above-code standard during construction

3. Controlling interior air movement through compartmentalization and firestopping, always tested during construction[vii]

Past studies have shown that housing quality improvements can improve resident health. Although the specific interventions vary from study to study, health benefits have been associated with integrated pest management and reduction of water and moisture infiltration to reduce mold (source control) and with improving mechanical ventilation (removal).[11]

Removing In-Building Fossil Fuel Combustion

Fossil fuel-burning equipment and appliances that may be present in homes include furnaces and boilers, domestic hot water (DHW) heaters, gas fireplaces, clothes dryers, and gas stoves and ovens. Gas stoves and ovens usually affect indoor air quality more than furnaces, boilers, and DHW heaters because these latter appliances are generally required to be vented to the outdoors, whereas the former are not.[12]

The undesirability of introducing combustion-related pollutants into the home has long been acknowledged in health literature.[13] Several health and housing interventional studies (studies that include the implementation of a health intervention in the study design) have included the removal of fossil fuel-burning appliances as a source control measure. These studies have found that removing indoor fossil fuel combustion reduced exposure to harmful pollution.[14]

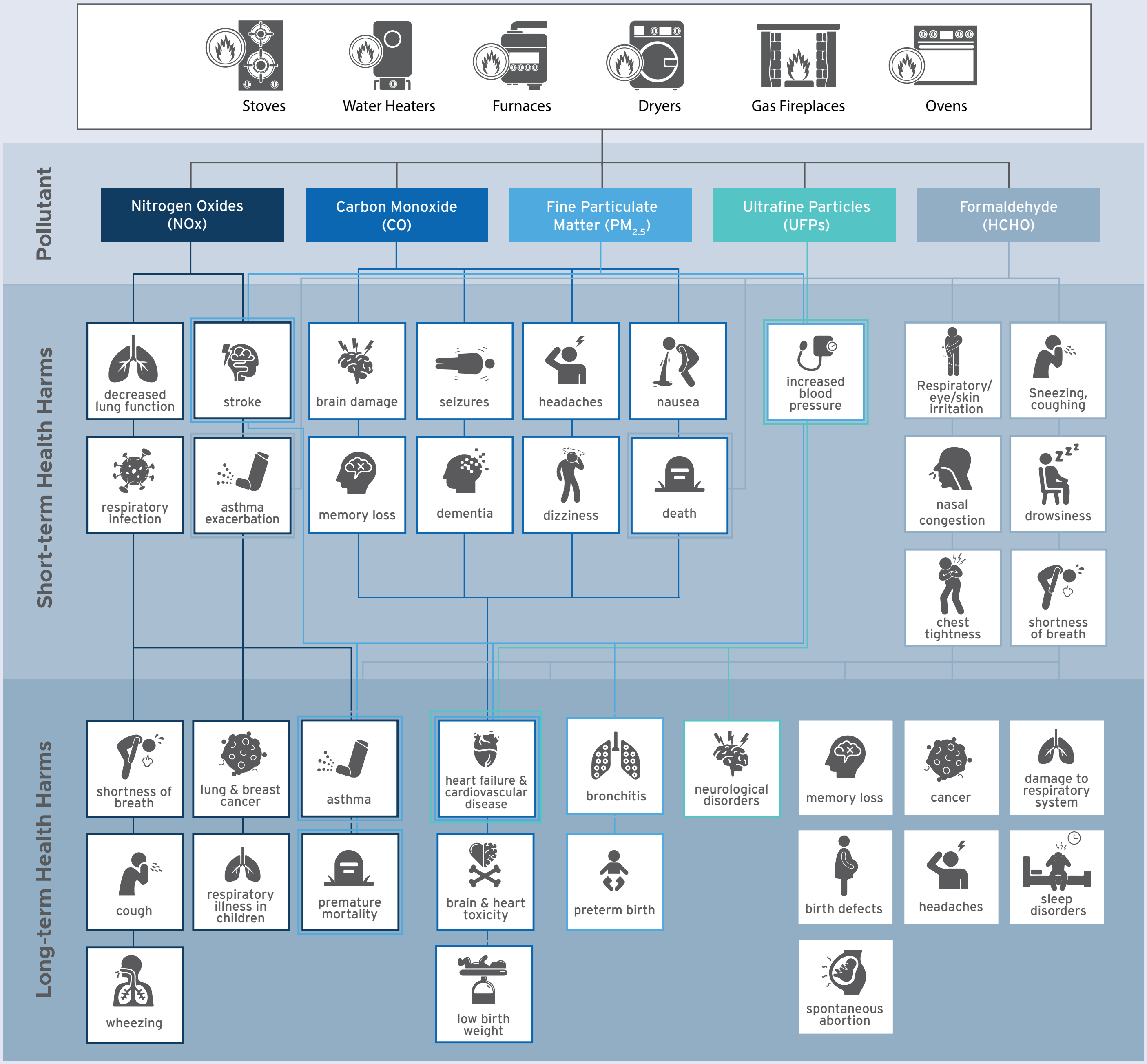
Pollutants resulting from fossil fuel combustion—including nitrogen oxides (NOx), carbon monoxide (CO), fine particulate matter ($PM_{2.5}$), ultrafine particles (UFPs), and formaldehyde (CH_2O)—are linked to a variety of adverse health impacts (see Exhibit 2). Removing sources of indoor pollution would immediately reduce the risk of the following health harms:

[vii] "Firestopping" refers to compartmentalization for the purpose of preventing the spread of fire via uncontrolled air movement. Firestopping is often verified through visual inspection rather than instrumented testing. In high-performance buildings, compartmentalization is subjected to instrumented testing when the walls are open, and any deficiencies can be addressed. Because air movement is hard to detect without instrumented testing, visual inspections should always be supplemented by instrumented testing.

Exhibit 2

Overview of Health Harms from Exposure to Pollutants from Fossil Fuel Combustion

In the home, appliances that burn fossil fuels, such as water heaters, furnaces, stoves/ovens, clothes dryers, and gas fireplaces emit several health-harming pollutants. It is well-documented that exposure to these pollutants over both the short and long term can have serious health impacts.



Note: Sources for Exhibit 2 are detailed in endnotes 15–40.

A comprehensive meta-analysis of 36 years of research found that children living in homes with a gas stove are 42% more likely to experience asthma symptoms and 24% more likely to be diagnosed with asthma by a doctor, compared with children living in homes with electric stoves.[41] Cooking with gas has been shown to create spikes in nitrogen dioxide (NO_2) and carbon monoxide at levels that would violate outdoor pollutant standards.[42] Numerous studies have shown that inhaling NO_2, even at levels below national standards, is detrimental to human health. A key epidemiological study of 1,342 asthmatic children found that their asthma worsened when they were exposed to low levels of NO_2 (as low as 11 parts per billion).[43]

High-Performance Envelopes, Compartmentalization, and Ventilation

Controlling the movement of air, vapor, water, and heat throughout a building and its envelope is fundamental to well-constructed buildings. A correctly implemented package of high-performance envelope construction, in-building compartmentalization and fireproofing, and high-efficiency mechanical ventilation can inhibit mold growth, prevent pest infestations, inhibit the distribution of airborne allergens among apartments, and prevent the intrusion of outdoor air pollution, including particulates and NOx.

Pollution Control and Removal

High-performance envelopes and interior compartmentalization use a variety of materials, technology, and tools, along with a close attention to design and installation details, to ensure that these four elements (air, vapor, water, and heat) stay where they belong. This means keeping heat in or out (depending on the season), preventing vapor from condensing within the envelope assembly, and keeping water out. High-performance envelopes (for example, in any passive house building) should always be tested during construction to make sure they are intact and meet the designed air infiltration specifications.

Passive House Buildings

Passive house buildings are those built according to the standards of Passive House International (PHI), Passive House Institute US (PHIUS), or the forthcoming ASHRAE Standard 227P, "Passive Building Design Standard."

Passive house design strategy carefully models and balances a comprehensive set of factors to keep the building at comfortable and consistent indoor temperatures throughout the heating and cooling seasons while keeping energy usage to a minimum. Passive house building projects use tools and follow protocols throughout the design and construction process to attain a deep, quantifiable level of energy efficiency within a quantifiable comfort level.

To that end, a passive house building will include:

1. continuous insulation employed throughout the entire envelope without any thermal bridging,
2. an extremely airtight building envelope that prevents infiltration of outside air and loss of conditioned air,
3. high-performance windows and doors for heat management,
4. some form of balanced heat- and moisture-recovery ventilation, and
5. a space conditioning system sized accordingly to the resulting smaller load.[44]

The established framework and rigorous testing for optimal building performance and pollutant control makes incorporating passive house design strategy compatible with the outcomes that beneficial electrification aims to achieve.

One important purpose of high-performance envelopes and compartmentalization is to ensure that mechanical ventilation systems function as designed. In "leaky" buildings, "fresh" air sneaks in wherever it can, and due to stack effect, it often escapes in much the same uncontrolled way, even when mechanical ventilation is present. When the envelope, interior compartmentalization, and ventilation systems are designed to work together, the benefit is control: the air comes in only where it's designed to do so, it can then be filtered as well as tempered, and it exits through the designed exhaust.[viii]

Recent findings suggest that ventilation systems should also maintain relative humidity between 40% and 60%, the range both supportive of immune response and most unfavorable to survival of microorganisms that can cause respiratory infections.[45] Well-sealed and compartmentalized buildings enable a degree of control over air movement that is simply not possible in "leaky" buildings.

Indoor Environmental Quality and Health

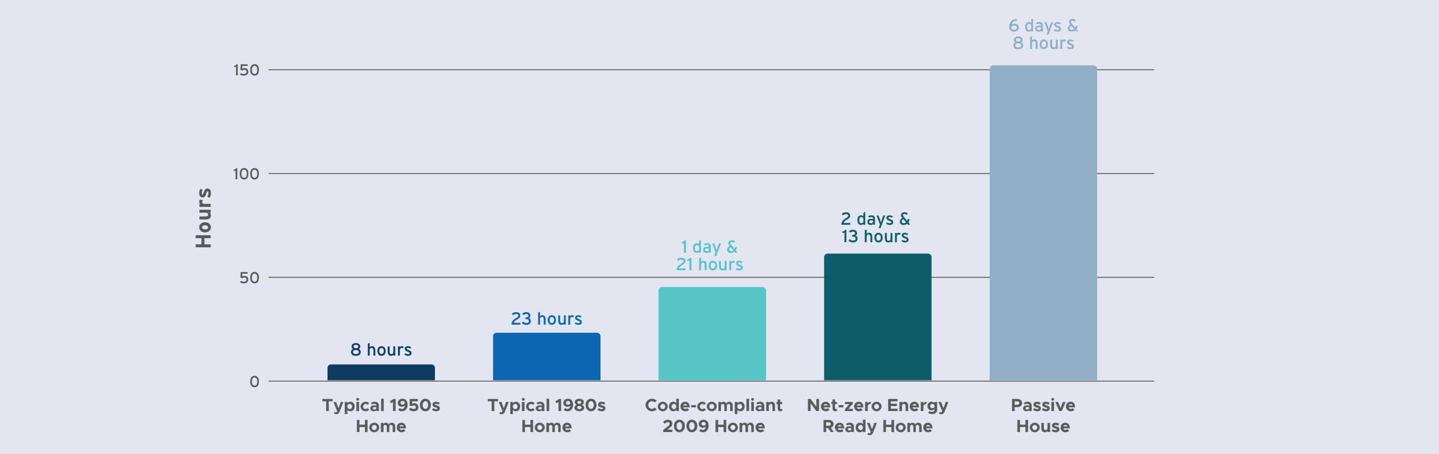
Evidence suggests that integrated pest management and eliminating moisture intrusion can provide health benefits by reducing indoor allergens and toxins. A systematic review of healthy housing interventions reported promising evidence (albeit evidence requiring more field evaluation) of benefits from ventilation and envelope sealing.[46]

A different systematic review by the DOE found statistically significant improvements in indoor air quality from improved ventilation.[47] Pollutants that were reduced by ventilation included known respiratory triggers such as airborne mold, formaldehyde, and other volatile organic compounds. The installation of enhanced ventilation has also been associated with fewer asthma and respiratory symptoms.[48] Among the studies reviewed, a simulation of the effects of different types of energy retrofits implemented at an affordable housing site in Boston found retrofits combining air sealing and ventilation to be the most protective of health.[49]

Sealed envelopes and compartmentalization also help to reduce pest infestations. Specifically, in existing buildings, remedially caulking and sealing visible and accessible gaps that were not properly sealed at the time of construction or that have developed over time can prevent pest entry and close pests' pathways to food and water.

In the event of power outages, high-performance envelopes may provide increased "hours of safety," maintaining safe indoor temperatures during hot or cold weather. RMI analysis of energy models found that passive house buildings can maintain indoor temperatures above 40°F for six days during a cold weather event, four days longer than a new, code-compliant building.[50]

Exhibit 3 Time to Fall Below 40°F in a Power Outage



Source: Sneha Ayyagari, Michael Gartman, and Jacob Corvidae, *Hours of Safety in Cold Weather*, RMI, 2020, **https://rmi.org/insight/hours-of-safety-in-cold-weather/**

[viii] Where present, ventilation ducts should also be sealed so that no air migrates in or out through gaps. Airflow at each register should be regulated to remove or deliver air at the designed rate.

Increasing Access to Air Conditioning for Health and Safety

Extreme heat—hotter summers, frequent and prolonged heat waves, and higher peak temperatures—ranks among the deadliest effects of climate change. According to the US Environmental Protection Agency (EPA), heat is already the nation's leading weather-related killer.[51] Across major cities in the United States, heat waves are more frequent than ever, from an average of two heat waves per year during the 1960s to more than six a year during the 2010s.[52] The average heat wave season in 50 major cities is 47 days longer than it was in the 1960s.[53]

Health Impacts of Extreme Heat

Heat-induced health conditions range from the uncomfortable (heat rash) to deadly (heatstroke). Heat exhaustion, for example, is a response to excessive sweating and the resulting loss of water and salt. Symptoms include headache, nausea, dizziness, weakness, irritability, thirst, heavy sweating, elevated body temperature, and decreased urine output. Heatstroke occurs when the body's temperature-regulating mechanisms fail, and it is fatal if left untreated. Symptoms include confusion, slurred speech, loss of consciousness, seizures, and very high body temperature.[54]

High temperatures can also contribute to deaths from heart attacks, strokes, and other forms of cardiovascular disease.[55] Deaths from heat-induced exacerbations of both natural causes and chronic conditions are far more common than heatstroke deaths. In New York City, for example, an average of 10 people die of heat stress annually, 100 die of chronic conditions exacerbated by extreme heat, and 350 die of natural causes exacerbated by heat.[56]

Among the most vulnerable to the effects of extreme heat are the elderly, children (especially infants), those with underlying physical or mental health conditions, residents of urban areas and low-income census tracts, and workers engaged in heavy manual labor.[57] Of these groups, infants under 1 year of age and the elderly are at the highest risk of mortality.[58] In addition, a 2016 meta-analysis found that a 1°C temperature rise increased rates of disease from cardiovascular, respiratory, diabetes mellitus, genitourinary, infectious disease, and heat-related issues.[59] Heat exposure can also worsen mental health and renal conditions.[60]

Hot weather too severe for human tolerance is already here and projected to get worse. The limits of human survival peak at wet-bulb temperature values of about 95°F (35°C), but serious impacts can occur at values as low as 79°F (26°C).[ix] Some regions in the United States, particularly the Southeast, are already experiencing multiple incidences of conditions at or near this survivability limit.[61]

[ix] Wet-bulb temperature is the lowest temperature that can be obtained through evaporative cooling, which is related to humidity. At wet-bulb temperatures of 95°F (35°C) and above, the body loses the ability to dissipate heat by sweating.

Cooling Technology as Protection

Cooling technology, such as air conditioning in the home, is the most effective protection against heat-related illnesses.[62] AC has been shown to significantly reduce the effect of high temperatures on severe health conditions (such as heart attacks, stroke, respiratory disease, pneumonia, dehydration, heatstroke, and diabetes).[63]

In research conducted by the City of New York on heat-related emergency room visits, hospital admissions, and heat-related deaths, the most deaths resulted from high-heat exposure at home.[64] Where the presence or absence of AC was noted, the deceased lacked AC (81%), or the AC was not working or in use (19%).[65] The most frequently cited reason for not using the AC was the cost of running it, which can be a tremendous barrier for low-income families.

In historically cold-climate areas that use fossil fuel-burning heating equipment, AC has long been considered a luxury rather than a necessity. In New York City, for example, landlords are required by law to provide heat during winter to avert death and provide livable housing, but no analogous obligation exists for cooling in summer. While the Low-Income Home Energy Assistance Program (LIHEAP) provides financial assistance for both heating and cooling, 51% was allocated for heating assistance nationally, compared with 5% for cooling, from 2001 to 2019.[66] Additionally, despite having high summer temperatures, Kentucky, North Carolina, and West Virginia elect not to provide cooling assistance.[67]

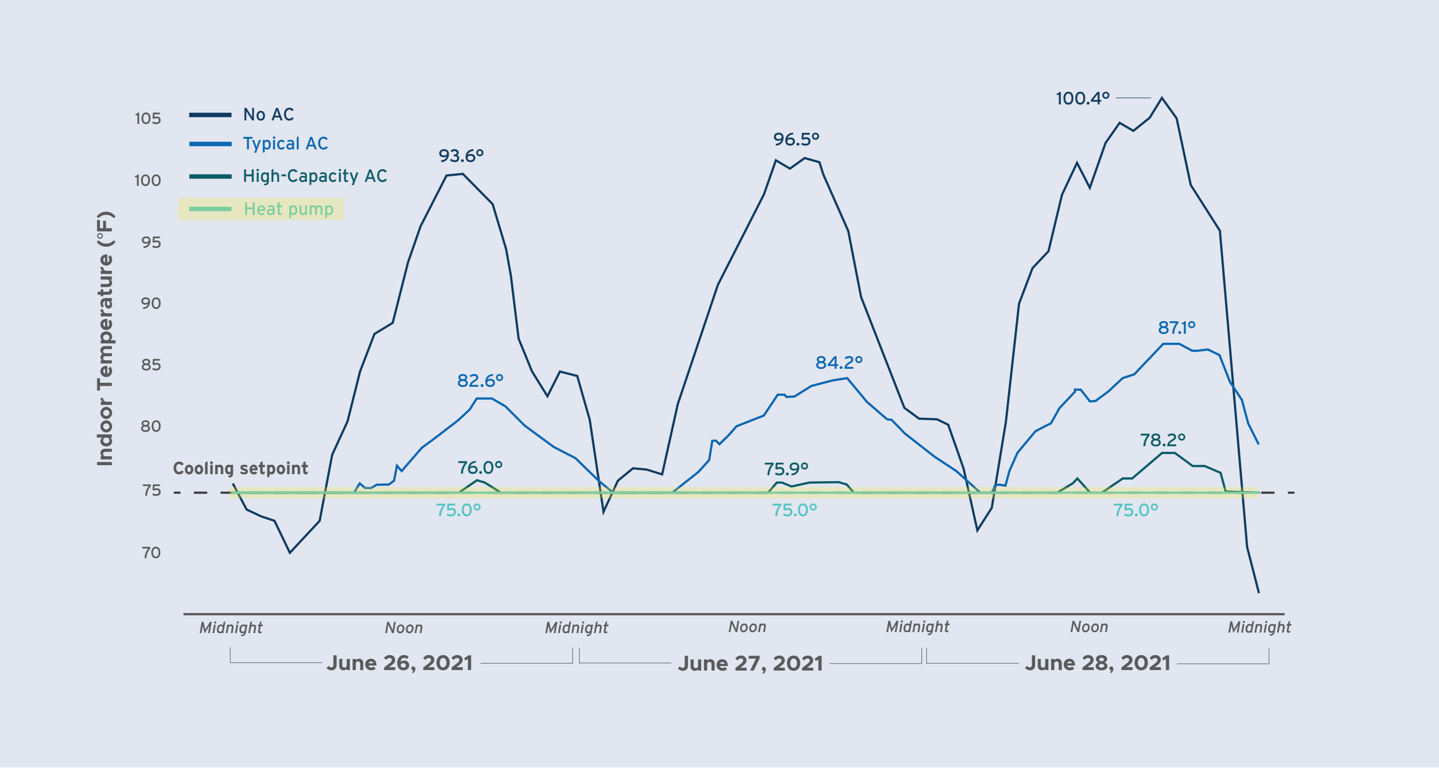
Heat Pumps for Climate-Aligned Cooling

High-performance envelopes can contribute to more efficient cooling, but modeling shows that they cannot fully mitigate the effects of daytime heat buildup in the absence of air conditioning when overnight temperatures stay high, as during heat waves.[68] Heat pumps, which provide both heating and cooling, are currently the best available heating and DHW-making technology in terms of minimizing potential GHG emissions.[69] Because extreme heat is deadly and likely to become more frequent, the need to provide air conditioning should be weighed when evaluating heating options.

RMI modeled the performance of several cooling scenarios for a Seattle home during an extreme heat event and found that an air-source heat pump was superior at maintaining a comfortable and safe indoor air temperature during extreme heat (Exhibit 4).[x] The heat pump was able to consistently maintain a safe indoor environment (cooling setpoint of 75°F), while also consuming less electricity than the high-capacity AC.

The heat pump also costs less per year to operate than a dual-fuel cooling and heating system (AC unit plus gas furnace) while reducing CO_2 emissions from the entire home by about 25 percent. The use of electric induction stoves is another attractive solution, as they can maintain a safe and comfortable indoor environment by heating cookware without open flames, thus minimizing cooling loads and keeping energy consumption and costs down.

Exhibit 4 **Seattle home cooling scenarios during extreme heat**



Source: Lacey Tan and Mohammad Hassan Fathollahzadeh, "Why Heat Pumps Are the Answer to Heat Waves," RMI, August 21, 2021, https://rmi.org/why-heat-pumps-are-the-answer-to-heat-waves/

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[x] The analysis compared the performance of an air-source heat pump, a typical AC unit, and a higher-capacity AC unit during a three-day heat wave in June 2021. The heat pump had a seasonal energy efficiency rating (SEER) of 22, whereas the AC was a SEER 18 model, based on the assumption that customers in a heating-dominant region would more likely choose a SEER 22 heat pump (which provides both heating and cooling) over a SEER 22 AC.

Reducing Health and Safety Risks to Neighborhoods and Communities

Neighborhood Outdoor Air Quality

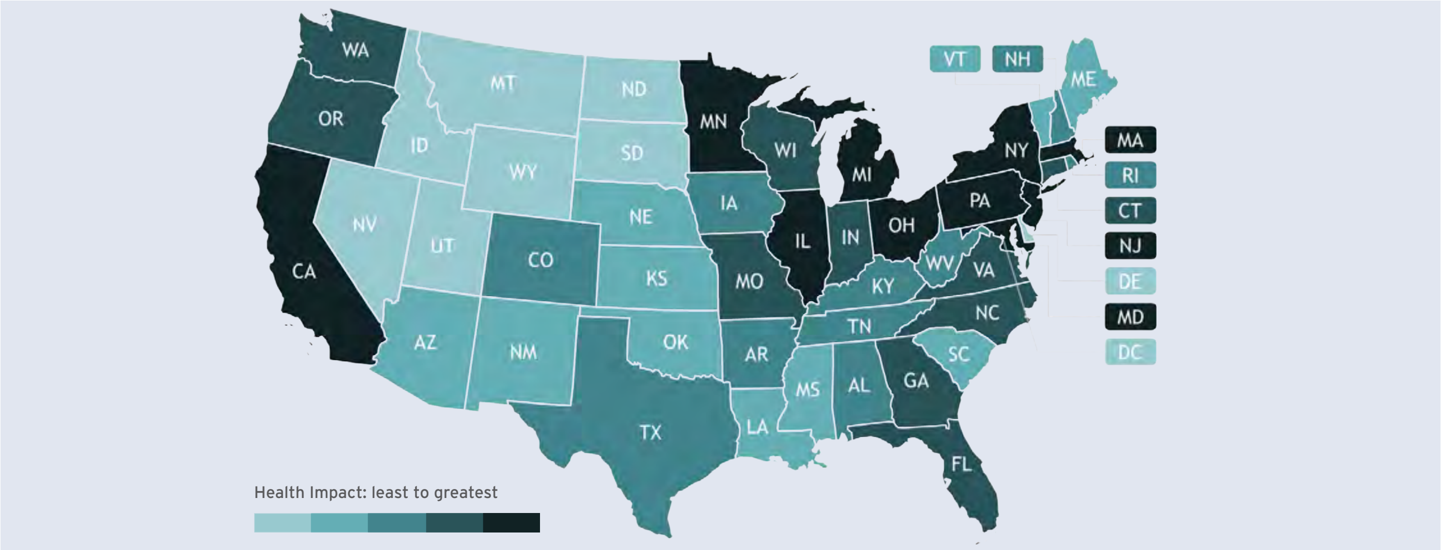
Burning fuels in buildings worsens neighborhood air quality. Long-term exposure to combustion-related air pollution, even at low levels, poses a significant risk to cardiovascular and respiratory health among the elderly. According to a study from the Harvard T.H. Chan School of Public Health, long-term exposure to NO_2, $PM_{2.5}$, and ozone increases the risk of several serious cardiac and respiratory conditions in older adults, including pneumonia, heart attack, stroke, and atrial fibrillation (an irregular, often rapid heartbeat).[70]

Modeling of air pollution sources shows that buildings are a significant source of outdoor air pollution. Among the emissions sources ($PM_{2.5}$ and ozone) evaluated in a study in the journal *Nature*—including the road, electric power generation, industry, marine, rail, and aviation sectors—the commercial and residential buildings sector is the most important sector contributing to estimated early deaths.[71] Additional research from the Harvard T.H. Chan School of Public Health shows that as coal-fired power plants closed during the past decade, the health burden shifted to burning fuels like gas, oil, wood, and biomass in other stationary sources.[72]

Burning fuels in buildings accounts for one-third of the total health impact of all stationary sources of combustion-related $PM_{2.5}$ air pollution in the United States (power plants, buildings, industrial boilers, and other industrial facilities).[73] An analysis of the health toll from buildings in 2017, the most recent available data, finds that between 15,000 and 20,000 premature deaths resulted from outdoor $PM_{2.5}$ air pollution from burning fuels in residential buildings. An estimated 2,000 to 3,500 additional early deaths were attributed to commercial buildings. Those early deaths equate to a national annual health burden of approximately $160 billion to $220 billion from the residential sector and $23 billion to $39 billion from the commercial sector.[74]

On a state level, a study conducted by the UCLA Fielding School of Public Health examined the potential benefits if all residential gas appliances in California were immediately replaced with clean electric alternatives. The researchers found that this would result in approximately $3.5 billion in monetized health benefits over the course of one year and over 350 lives saved, just from the associated reductions in outdoor NOx and $PM_{2.5}$.[75] Accounting for both indoor and outdoor exposures would increase the total health benefits and associated economic benefits of residential electrification.

Exhibit 5 Outdoor Air Pollution Health Impacts from Burning Fuels in Buildings



Source: Brady Seals, Leah Louis-Prescott, "What is the Health Impact of Buildings in Your State?" RMI, May 5, 2021, **https://rmi.org/health-air-quality-impacts-of-buildings-emissions**

Safety Risk to Communities and the Environment

The US gas distribution infrastructure—often disproportionately located in areas of high social vulnerability—is aging and inherently at risk of fires and explosions.[76] Many factors play a role in these incidents, including leaky gas supply lines inside and outside homes, overpressurization of gas mains, and accidental damage during construction. Additionally, gas infrastructure is vulnerable to climate extremes including wildfires, floods, and sea level rise, as well as other environmental hazards like earthquakes.[77]

The US Pipeline and Hazardous Materials Safety Administration found that a gas pipeline incident kills someone, sends someone to the hospital, or causes a fire or explosion every four days, on average.[78] Additionally, there are many examples of dramatic incidents related to gas infrastructure in residential and commercial settings, such as those in San Bruno, California, in 2010 and Andover, Massachusetts, in 2018.[79] The National Fire Protection Association reported that local fire departments have attended annually to an average of 125,000 household natural gas leaks and 4,200 home structure fires caused by natural gas ignition. Those fires cause 40 deaths and 140 injuries a year.[80] Even small leaks contribute to the risk of fires and explosions in homes.[81]

Leaking supply lines and equipment in buildings are a significant source of fugitive methane in cities. Methane, a greenhouse gas, can have more than 80 times the global warming impact of CO_2 over a 20-year period when leaked directly into the atmosphere.[82] In a 2019 study of methane leaks, a vast majority (more than 84%) of leaks in the five biggest urban areas studied came from homes, businesses, and gas distribution infrastructure.[83]

At both a neighborhood and household level, the decommissioning of gas infrastructure would reduce the risks posed by gas distribution systems, whether from neighborhood air pollution, the risk of fire or explosions, or the exacerbation of climate change through GHG emissions.

Health Benefits from Improved Grid Reliability and Affordability

The reliability and affordability of the power system has an important impact on health. A systematic review of health research related to power outages found that health consequences range "from carbon monoxide poisoning, temperature-related illness, gastrointestinal illness, and mortality to all-cause, cardiovascular, respiratory, and renal disease hospitalizations, especially for individuals relying on electricity-dependent medical equipment."[84] A 2019 review of research on energy, poverty, and health found that energy insecurity—the inability to adequately meet basic household energy needs—affects a wide range of health issues, from stress and mental health to poor sleep and cardiovascular and respiratory health.[85]

Electricity outages also result in direct health harms when residents use improperly vented gas generators and other fuel-burning equipment for heat. Carbon monoxide poisonings consistently occur across the United States but made national headlines following the 2021 winter storm in Texas, where conservative estimates included 11 deaths and over 1,400 cases seen in emergency rooms and clinics.[86] Many of the carbon monoxide poisoning cases were caused by operating vehicles in unventilated garages for warmth and by indoor use of fuel-burning household appliances like charcoal grills, camp stoves, and portable generators. Children, people of color, and individuals living in lower-income communities were disproportionately affected by carbon monoxide poisonings.[87]

Beneficial Electrification Strategies for the Grid

The DOE identified extreme weather as a leading environmental risk to the electric grid, noting that transmission, storage, and distribution infrastructure is vulnerable to many natural phenomena such as hurricanes, earthquakes, drought, wildfires, flooding, and extreme temperatures.[88] As these extreme weather events become more frequent and intense, so does the threat to the grid's reliability in meeting human needs.

As new consumers are added to the grid and existing gas equipment and appliances transition to electric appliances, demand for electricity will increase. Strategies should be adopted to ensure grid affordability and reliability, which will become even more critical as climate change increases grid demand.[89] To mitigate potential negative consequences resulting from this increased demand, beneficial electrification efforts must smooth out demand peaks. This can be achieved by pairing electrification with high-efficiency building upgrades, by using technology appropriate to the local climate such as cold climate heat pumps, and by adopting flexible demand technologies like smart water heaters, smart thermostats, or energy storage.

Flexible strategies are key. For example, when there is excess supply of electricity, energy storage systems can charge up and heat pumps can heat water for later use.[xi] Keeping up a steady demand makes the system more efficient and can support system reliability. A 2021 study of the technical potential of US building-grid resources found that deploying building efficiency and flexibility together yields the greatest grid benefits.[90]

When the electric system does experience outages, building-scale or neighborhood-scale solutions can provide resilience benefits. These solutions range from high-efficiency building shells that maintain safe temperatures for longer, solar and storage at the building level or neighborhood level that can power critical loads, or even newer electric vehicles that can power critical needs or even whole-home power demand in some cases.[91]

[xi] On today's grid, this would happen at low-demand times. With enough renewables on the system, renewable production may overshoot the demand. Demand flexibility that can match output from renewables makes renewables more economic, while reducing the need for costly and polluting fossil fuel plants.

Part 2: Why Will Low-Income Communities Gain the Most?

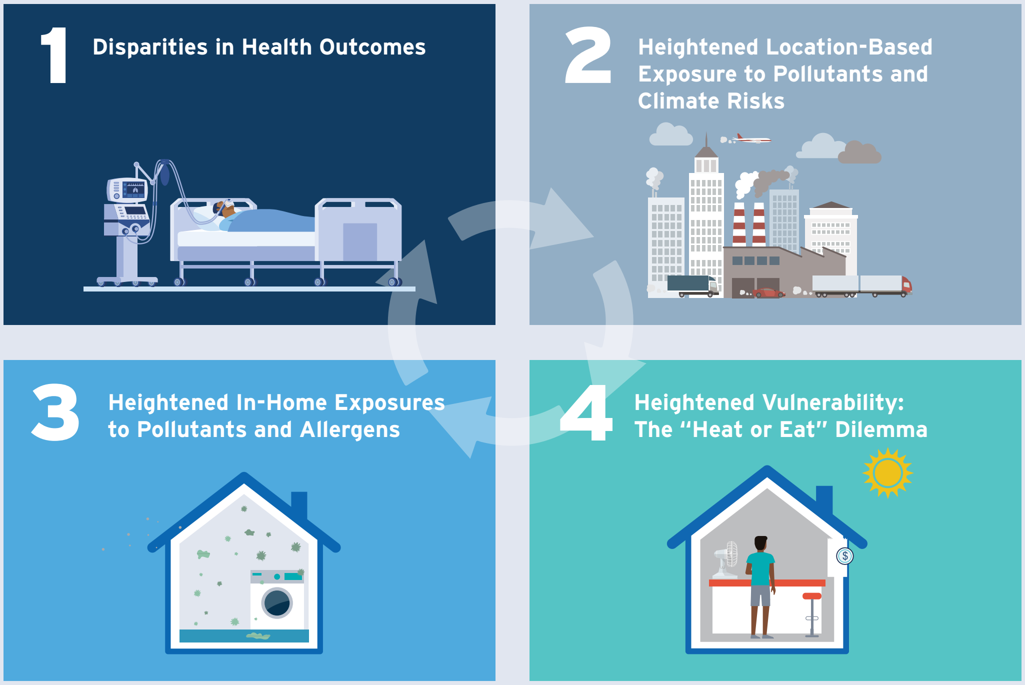
Part 2: Why Will Low-Income Communities Gain the Most?

Beneficial electrification's positive health and environmental impacts are particularly important for improving health disparities of overburdened and underserved communities and communities of color. Health disparities are the result of heightened exposure and heightened vulnerability. Beneficial electrification, both in retrofits and new construction, directly reduces exposure to a broad range of pollutants, allergens, and toxins within the home by preventing their introduction (control) and by venting them (removal). Beneficial electrification also reduces vulnerabilities related to energy insecurity and access to air conditioning.

Because heightened vulnerability acts as a magnifier of environmental risks, any reduction in exposure can diminish disparities, even when the exposure was not disproportionately high to begin with.[92] Heightened exposures directly related to housing include pollutants stemming from poor indoor and outdoor environmental quality. Housing-related vulnerabilities include those due to stress stemming from poverty, neighborhood conditions, and, in the case of low-income communities of color, decades of systemic racism.[93] These factors may be further exacerbated by workplace exposures and other non-housing social determinants of health.[94]

Exhibit 6 Why Low-Income Communities Need Beneficial Electrification (in Retrofits and New Construction)

Beneficial electrification's positive health and environmental impacts are particularly important for improving health disparities of overburdened and underserved communities and communities of color.



In New York City, for example, when the Mayor's Office projected the impact of its climate action plan, which included modeling the health and air quality benefits of electrifying buildings, it found that low-income neighborhoods would benefit the most. Its report estimated that electrifying large buildings would reduce asthma emergency room visits in the poorest neighborhoods 10 times more than in affluent neighborhoods—even though reductions in $PM_{2.5}$ were similar in all neighborhoods.[95]

Disparities in Health Outcomes

The United States has some of the largest income-based health disparities in the world. While life expectancy has risen among middle-income and high-income residents, it has stagnated among the poor and even declined in some groups.[96] It has been consistently shown that higher income is related to higher life expectancy and that lower income is related to lower life expectancy.[97] Poor adults are five times as likely as those with incomes above 400 percent of the federal poverty level to report being in poor or fair health.[98] Disparities in health burden as a function of socioeconomic status is clear: low-income people have higher rates of heart disease, asthma, and other chronic conditions, compared to higher-income people.[99]

Heart Disease

Household income has been strongly and independently associated with heart disease.[100] Traditional risk factors like hypertension, diabetes, and smoking have been shown to account for less than half of the burden of heart attacks and strokes among the less affluent. Instead, 60% of the burden of heart disease is attributable directly to living in poverty and its associated risks.[101] A large study in the United States found an increased risk of cardiac events (nonfatal heart attack and sudden cardiac death) in low-income cohorts in comparison to higher-income cohorts, which persisted even after adjusting for other risk factors such as race, smoking, and alcohol consumption.[102]

Asthma

Low-income communities are disproportionately burdened by asthma. A study of New York City, for example, found that the prevalence of asthma in children growing up in lower-income East and West Harlem neighborhoods is two to three times higher than in bordering wealthier neighborhoods.[103] Additionally, the lower-income communities of East New York and the South Bronx are two of the most asthma-ridden neighborhoods in New York City.[104] This pattern persists throughout the United States: asthma is more prevalent in children living in low-income families (with an incidence of 10.5%) than among those living in families with income above the federal poverty level (approximately 6%–9%).[105]

Heightened Location-Based Exposure to Pollutants and Climate Risks

Low-income people and communities of color continue to experience heightened exposure to pollutants resulting from decades of exclusion and race-based segregation.[106] Low-income communities live in closer proximity to mobile and stationary polluting sources such as highways, power plants, toxic waste sites, and landfills.[107] These groups are exposed to toxins or hazardous conditions at levels well above those recommended for healthy, safe environments.[108]

The urban and social policies that have increased exposures to pollutants and toxins are now proving to have the same effect for climate risks.[109] Residents of low-income neighborhoods endure far higher outdoor temperatures than people who live in wealthier areas.[110] A study of 175 urban areas found that over 70% of people with an income below the poverty line had a significantly higher exposure to surface urban heat than people with an income more than double the poverty line.[111] In some cities, the difference in summer surface temperatures between redlined and non-redlined neighborhoods can be as high as 20°F.[112]

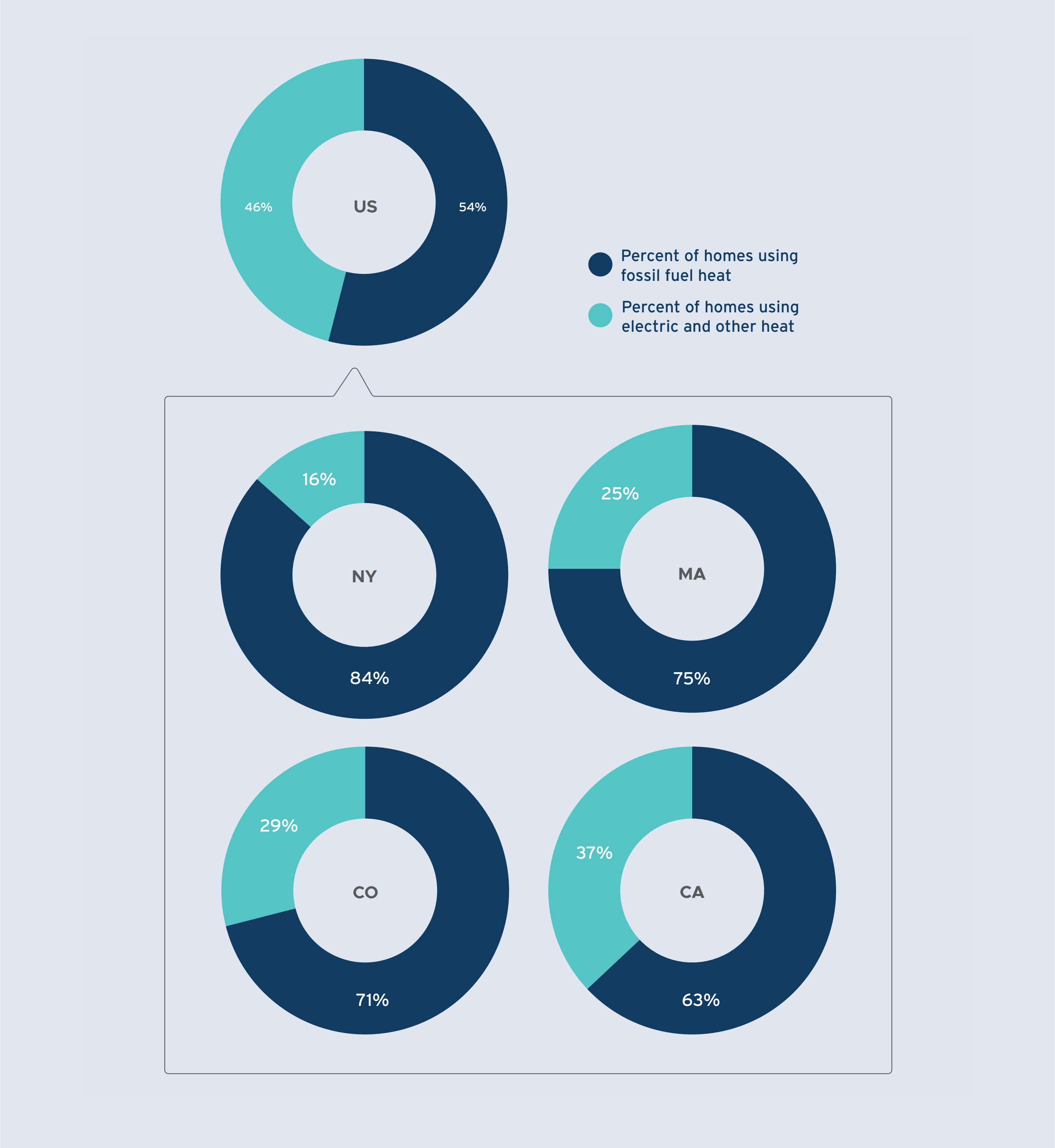
Analysis: How Are Homes Heated?

RMI analysis of data provided through the DOE's Low-Income Energy Affordability Data (LEAD) tool reveals the burden of fossil fuel combustion in low-income households.

Across the United States, RMI analysis found that 54% of low-income residential homes are heated by fossil fuels including piped natural gas, bottled gas such as propane, and fuel oil.

Additionally, out of the four states selected by RMI for analysis, New York's low-income residential units are the most fossil fuel-intensive for heating, while California is the least.[113] In New York, 84% of low-income homes use piped natural gas, bottled gas (such as propane), or fuel oil to heat units.

Exhibit 7 Primary Heating Source for Low-Income Residential Dwelling Units



Source: RMI analysis of the DOE LEAD tool

Heighted In-Home Exposures to Pollutants and Allergens

A large portion of the US housing stock suffers from housing quality deficiencies linked to health consequences, and low-income residents are more likely to live in homes with the most serious deficiencies. Based on 2017 American Housing Survey data, US government agencies estimate that nearly a third of all occupied housing and almost half of rental housing exhibited housing quality deficiencies, such as structural, plumbing, electrical, and heating problems, leaks, or pest infestations.[114] In rental housing specifically, a federal analysis found "serious deficiencies more often affected households with extremely low incomes or rent burdens. In addition, lower-income households rented approximately two-thirds of the units with substantial quality issues and nearly 80 percent of units lacking essential components."[115]

In addition to exposures to mold- and pest-related allergens that directly stem from water leaks and pest infestations, which are traditionally used as indicators of housing quality, low-income residents are subjected to pollutants from fossil fuel combustion. Nationally, more than half of homes occupied by low-income residents are heated with fossil fuels (Exhibit 7). Furthermore, research seeking to quantify racial disparity in $PM_{2.5}$ exposure found that burning gas in residential buildings is among the most inequitable sources of pollution.[116]

Exposure to combustion by-products resulting from the use of stoves or ovens as supplemental heat is closely tied to energy insecurity. Ovens improperly used as heating devices often produce levels of pollution that exceed public health guidelines.[117] Low-income households are twice as likely as high-income households to use unvented stoves or ovens as supplemental heat.[118] The use of a gas stove or oven for supplemental heat is a main risk factor for pediatric asthma. Children under age 6 who live in homes that use a gas stove or oven for supplemental heat are 80% more likely to have asthma than children in homes that do not.[119]

Heightened Vulnerability: The "Heat or Eat" Dilemma

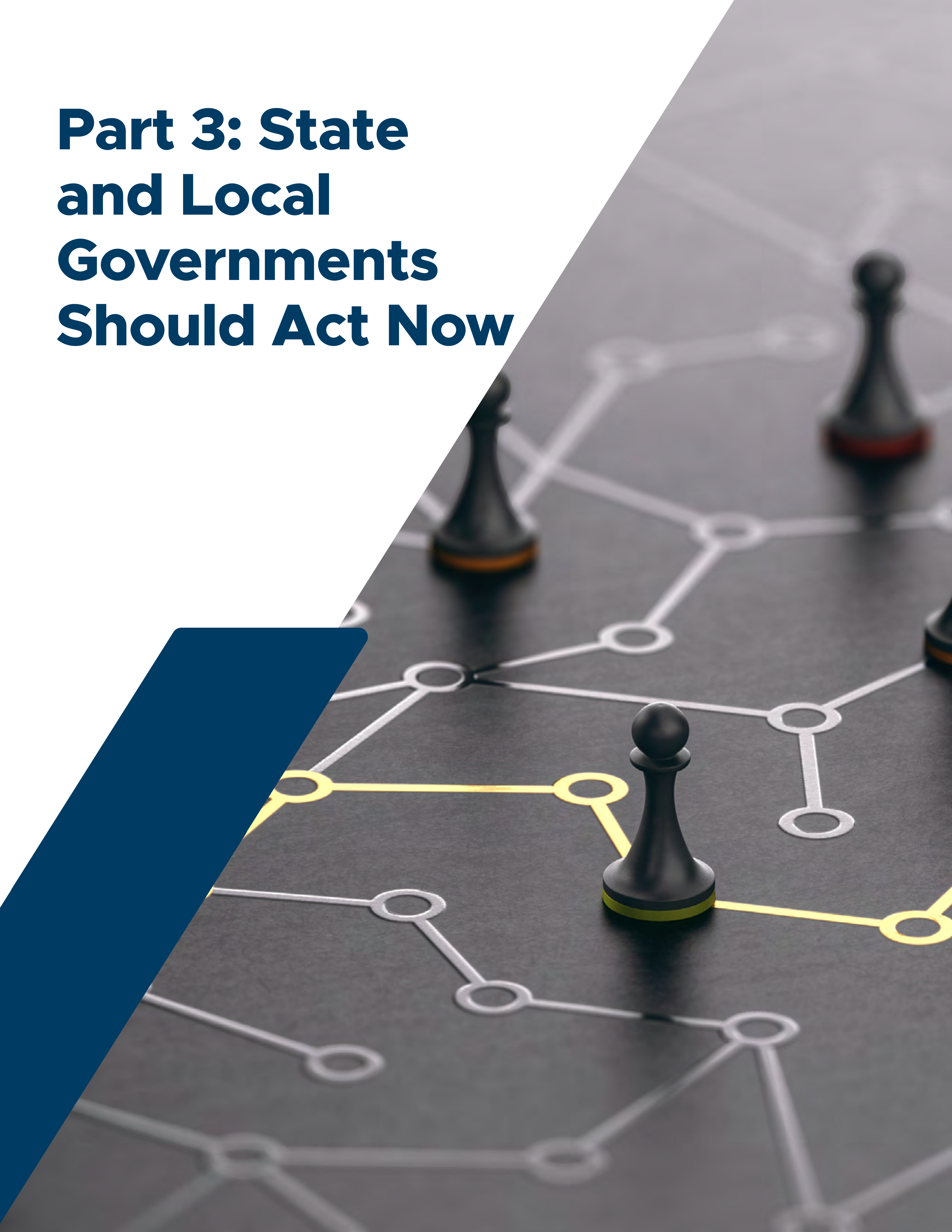
In 2019, 37.1 million low-income households (nearly 30% of all US households) earned less than $25,000 and spent more than 30% of their income on housing. This group made up three-fifths of US renters and one-fifth of US homeowners. Cost burden rates were higher for households of color than for white households.[120]

For low-income families, the cost of residential heating, cooling, and other energy needs constitutes a larger share of their income than for more affluent families, which necessitates difficult trade-offs.[121] The "heat or eat" dilemma exemplifies the trade-offs that low-income, at-risk households must make to meet the necessities of life, often sacrificing one need for another.[122] The US Energy Information Administration found that one in five households in 2015 reported reducing or forgoing necessities such as food and medicine to pay an energy bill.[123] DOE's LEAD tool data also shows that the average energy burden for low-income households nationally is three times greater than for higher-income households.[124] These financial pressures contribute to toxic stress that exacerbates health conditions.[125]

The "heat or eat" dilemma is also a "cool or eat" dilemma. According to the 2019 American Housing Survey, an estimated 91% of households had air conditioning. However, among households with no AC, households making less than $30,000 per year were overrepresented and those making $60,000 or more were underrepresented.[126] Furthermore, among residents without air conditioning, 30% lived in the highest-poverty neighborhoods, versus just 1% in the lowest.[127]

There are fundamentally two ways to reduce energy cost burdens: reduce the amount of energy needed for necessities, or restructure utility rates so that system costs are shared more equitably according to customers' ability to pay. Comprehensive energy efficiency scopes of work, whether in new construction or in existing housing, together with electrification, can reduce energy consumption. In tandem, electricity rates must be designed both to accelerate adoption of electric equipment and to reduce ongoing costs for low-income customers.[128] Achieving energy affordability through beneficial electrification and rate redesign will ease the burden on resource-constrained households and free them from trade-offs that jeopardize health and safety.

Part 3: State and Local Governments Should Act Now



Part 3: State and Local Governments Should Act Now

Countless historical precedents signal that actions to mitigate or adapt to climate change will not equitably distribute their benefits, redress existing inequities, and dismantle institutional racism without clear intent and political will to do so. For this reason, and to support the self-determination and agency of low-income communities, state and local governments should explicitly create resources and frameworks that center community-based and community-rooted organizations as partners in policymaking.

Although US housing policy is largely centralized in the federal government through its control of direct and indirect subsidies, only about 5 million households receive housing subsidies from the federal government, a small fraction of the total low-income households in need.[129] Federal weatherization assistance support only reaches 35,000 households per year.[130]

State and local governments are in the driver's seat in setting local policies and housing quality standards, and they can take independent action without waiting for the federal government. State and local policymakers can also advocate for federal initiatives to support beneficial electrification in housing.

The cost of transitioning to a fully renewable electric grid by 2030 is estimated to be $4.5 trillion, including $700 billion in transmission investments.[131] In comparison, remedying all housing deficiencies nationwide is estimated to cost $126.9 billion.[132] Policymakers should prioritize beneficial electrification of housing because it represents a small investment in the context of the larger energy transition, but it uniquely delivers important health and equity benefits.

As with many other aspects of climate action, delays today may mean not only worse outcomes in the short term, but also higher costs and greater difficulty in the long term. Evolutions of building and housing quality standards have historically followed crises—the great fires of the 19th century, cholera epidemics, and so on. Impacts of the climate emergency, some of which are already in evidence, will only compound a health emergency that is proven to be closely tied to housing quality. It is time once again to examine housing quality based on the overwhelming evidence that poor-quality housing causes health harms and health disparities—and to act by improving standards.

State and local governments can take several actions today. The actions below are detailed in the following sections.

1. Adopt enabling policy frameworks for accountability to and agency of low-income communities.
2. Build market capacity and increase funding for existing programs, particularly affordable housing programs, to align with beneficial electrification of housing.
3. Revise codes and standards to expand the reach of health-focused housing initiatives.
4. Advocate for federal initiatives that would make it easier to pursue deep carbon reductions and beneficial electrification in housing.

Adopt Enabling Policy Frameworks for Accountability to and Agency of Low-Income Communities

1. Institutionalize commitment to low-income communities in beneficial electrification policies.

Formal action at the state and local level can address the outsize health and socioeconomic burden that low-income communities have historically endured and continue to endure. The New York State Climate Leadership and Community Protection Act (CLCPA) prioritizes public investment in these communities by explicitly directing resources to them. The CLCPA provides that these communities should receive no less than 35% (with a goal of 40%) of the overall benefits of spending on clean energy and energy efficiency programs.[133] New York also established the Climate Justice Working Group to ensure that environmental justice and climate justice organizations would have a substantive role in informing statewide policies.

2. Energize community development corporations (CDCs), community-based organizations (CBOs), and community-rooted leaders to shape beneficial electrification policies.

Community leadership must be an essential part of the policymaking process for decarbonization at every level of government. The community development field, which includes building and managing affordable housing, is already well endowed with CDCs, CBOs, and local leaders who come from and enjoy the trust of the communities they serve. CDCs and CBOs, through decades of affordable housing development and stewardship, have demonstrated that they have a model of meaningful engagement that works. These organizations and leaders could become strong champions to ensure that beneficial electrification delivers the needed health benefits for low-income communities, but they must first come to value beneficial electrification as an important component of their community development missions.

CDCs and CBOs were able to grow from grassroots origins to become highly effective community development and real estate organizations because capacity-building resources were made available over decades to support them. It is critical that these community advocates now receive technical and financial support to meaningfully lead in beneficial electrification. There are three practical ways for policymakers to center community groups: to fund them to develop beneficial electrification plans, to enable participation and transparency in the process (for example, by providing research and analysis support and ensuring that typical technical jargon is understandable), and to provide funds so groups can hire dedicated staff.[134]

Several recently published guides are available to policymakers. The Greenlining Institute developed *Equitable Building Electrification: A Framework for Powering Resilient Communities and Making Racial Equity Real in Research*.[135] The NAACP has made available its *Guidelines for Equitable Community Involvement*.[136] The Urban Sustainability Directors Network published *Equity and Buildings: A Practical Framework for Local Government Decision Makers*.[137]

Use Public and Affordable Housing Programs to Build Market Capacity

Although privately built affordable housing and public housing serve only a fraction of low-income households in need, affordable housing programs present an important opportunity to lead the housing market toward new best practices.

Affordable Housing

Affordable housing most often refers to privately developed, federally subsidized housing that sets household income limits in qualifying beneficiaries. The largest such program is the Low-Income Housing Tax Credit program. More broadly, affordable or low-income housing may include public housing, developed and owned by governmental public housing authorities; rent-regulated housing, where a city or state sets maximum allowable rent increases; or "naturally occurring affordable" or "low-cost" housing that maintains low rents due to market conditions.

The residential real estate market is fragmented, with high information asymmetry, which makes it difficult to change prevailing practices by changing public policy. Affordable housing and public housing offer an opportunity for states and local governments to drive faster adoption of green building practices. Completed projects, in turn, serve as powerful rejoinders to arguments against the feasibility of such practices.

Most states already require above-code energy and sustainability performance in subsidized affordable housing projects, and many refer to third-party standards (most commonly LEED, Enterprise Green Communities Criteria, and US EPA Energy Star Homes). Over time, the consensus in the building performance field has evolved toward more stringent energy, envelope, and ventilation standards. These green building policies have made it easier for states to require that affordable housing adhere to the more stringent standards before they become incorporated in building codes.

As building electrification has become the new consensus among architects, engineers, and building scientists, it has been introduced as a voluntary measure in the 2020 Enterprise Green Communities Criteria and in LEED v4 as the GridOptimal Buildings pilot credit. For example, applicants for funding through the extremely competitive, points-based system for the 9% Low-Income Housing Tax Credit (LIHTC) in Pennsylvania receive a scoring advantage when their buildings are designed to the Passive House standard.[138] In this way, affordable housing developers have become reliable early adopters of green building approaches, and their successes stand as testaments to what can be built with existing technology (and the will to use it).

State and local governments can also use public and affordable housing programs to aid the commercialization of nearly market-ready technologies. The New York State Energy Research and Development Authority (NYSERDA), for example, points to the participation of the state's affordable and public housing owners in its building decarbonization programs. This publicizes the readiness of the market to manufacturers of advanced building materials like prefabricated and modular envelope retrofit systems.

To drive beneficial electrification in public and affordable housing, policymakers can:

1. Require all new affordable housing to be all-electric passive house construction by 2025.

Setting a 2025 deadline for the beneficial electrification of new affordable housing sends a clear market signal while allowing the construction market several affordable housing construction cycles to prepare. The years leading up to the deadline can be used to redesign funding program rules with input from affordable housing developers, assist first-mover developers to try out beneficial electrification, and to engage designers, contractors, and equipment manufacturers.

Cost is often the first consideration in efforts to reach climate and renewable energy goals. RMI analysis shows that in many parts of the country, all-electric new buildings are cheaper than or cost the same as mixed-fuel buildings.[139] Cities where a new all-electric, single-family home is less expensive than a new mixed-fuel home include Austin, Texas; Boston; Columbus, Ohio; Denver; Minneapolis; New York City; and Seattle. Such homes in Seattle can cost up to $4,300 less, while emitting 93% less GHGs.[140]

2. Create incentives for beneficial electrification of existing housing.

Most states and localities already have programs that incentivize preservation of affordable housing, maintenance of existing low-cost housing, and adopting energy efficiency and renewable energy. These programs should be increased and enhanced to enable beneficial electrification scopes of work. This may entail revising the annual plans for federal block grants and/or enabling multiple sources of funds to work together more easily. For example, utilities often provide customer energy efficiency incentives as rebates on a measure-by-measure, prescriptive basis.

This structure is harder to use alongside housing funding, and it reduces an owner's options for technology and construction strategies. It also detracts from "whole building" retrofit solutions that are needed to deliver the holistic benefits discussed above. Rebates and incentives for gas equipment such as high-efficiency boilers or furnaces should be phased out and reallocated to beneficial electrification. These types of programmatic misalignments should be addressed to enable more efficient flow of resources.

Reducing up-front costs and construction complexity will be particularly important to enable beneficial electrification of existing buildings at a large scale. Strategies to lower costs and streamline on-site retrofit work include prefabricated comprehensive retrofit packages, such as those being deployed in New York and by RMI's REALIZE-MA and REALIZE-CA programs.[141] Additionally, costs can be reduced by adopting portfolio-wide "zero-over-time" capital planning to align beneficial electrification with major building life-cycle events, such as major rehabs or refinancing events.[142] Construction costs are also intimately tied to construction market capacity and labor costs. State and local governments can encourage the entry of new firms, promote the use of off-site manufacturing techniques, and support existing contractors to adopt new technologies like heat pumps.

3. Require full accounting of health impacts and energy insecurity in benefit-cost analysis.

Energy efficiency and capital subsidy programs employ benefit-cost tests (savings-to-investment ratios, etc.) to limit investments to those deemed "economic." These benefit-cost formulas exclude any consideration of health impacts. Along with GHG reductions, policymakers and utility regulators should require inclusion of health and other non-energy benefits in the benefit-cost analysis of proposals for housing subsidies and utility demand-side programs. These should build in specific metrics that account for the disproportionate energy affordability and health impacts on low-income and communities of color.

4. Standardize and digitize data collection and adopt open data protocols.

Structured information about building performance and scope of work is rarely collected as part of the required reporting for energy and utility programs. This information could include data on airtightness, duct tightness, type of ventilation, ventilation rate, heating and DHW fuel, stove and oven fuel, presence of demand monitoring or demand controls, and more.

Not collecting this information is a missed opportunity. First, the lack of such data has hampered the ability of public health researchers to understand empirically the links between building performance and health outcomes.[143] Second, such details, particularly when coupled with actual cost information, would speed the growth of the market for such retrofits by resolving important information asymmetries. These asymmetries exist between owners and contractors with and without implementation experience, as well as for funders, investors, contractors, and equipment manufacturers. Last but not least, such transparency would facilitate individuals having a say in decisions that affect them.

Revise Codes and Standards to Expand the Reach of Health-Focused Housing Initiatives

Affordable housing subsidy programs only reach a small portion of low-income households. Revising codes and standards would expand the reach of health-focused housing initiatives to all residential buildings.

1. Set health-protective indoor temperature requirements including summertime maximum temperatures.

Setting maximum indoor summer temperatures will mobilize the housing industry to treat safety from extreme heat with the same seriousness and due diligence as safety from freezing temperatures or fires. There is currently no universally accepted upper threshold for safe indoor air temperatures. But under federal regulations, long-term care facilities certified after 1991 must maintain a temperature range of 71°F to 81°F, and the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommends 79°F as an upper temperature limit for comfort. A more sophisticated approach may include wet-bulb temperatures to align more closely with medical research.

2. Expand Building Performance Standards (BPS) metrics and increase adoption.

Fewer than 1% of US homes receive an energy-related upgrade each year.[xii] This pace of renovation is simply incompatible with achieving necessary GHG reductions. BPS is a regulatory tool to increase the pace of GHG-mitigating renovations, including beneficial electrification. BPS sets minimum performance requirements for existing buildings using metrics like GHG emissions, energy use per square foot, indoor air quality, and resilience metrics. The standards can be adopted at the city, county, or state level, or as a requirement by investors or lenders as part of a capital improvement plan or at the time of mortgage initiation.

States and cities currently considering BPS have expressed a strong interest in including indoor air quality and resilience metrics, but the policies adopted to date focus on carbon and energy metrics.[144] In adopting or expanding BPS to include non-energy benefits, policymakers must carefully consider the characteristics of the local housing market to ensure that BPS helps rather than hurts affordable housing.[145]

Jurisdictions that adopt BPS will also need to make sure that BPS and local codes do not conflict. Efforts like the Institute for Market Transformation's Building Performance Standards model ordinance provide helpful guidance for adding metrics, engaging affordable housing stakeholders in the design and implementation of the policy, and providing financing and technical assistance for upgrades in affordable housing.

3. Close loopholes in building, fire, and energy codes.

Local building codes should be revised to advance beneficial electrification. Building codes are often the result of decades of gradual evolution. Conditions that were once important to work around may have become maladaptive over time. For example, New York City code exempts kitchens under 80 square feet and bathrooms from mechanical ventilation if there is an operable window in proximity. Fixing such loopholes would

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[xii] This figure comes from a calculation by the Institute for Market Transformation, based on the Joint Center for Housing Studies at Harvard University's The State of the Nation's Housing 2019 and the EIA's Residential Energy Consumption Survey.

not only result in better indoor environmental quality, but also would change the baseline cost against which superior approaches (such as energy recovery ventilation) are compared.[xiii]

Numerous climate, health, and environmental justice groups advocated for an all-electric baseline for California's 2022 building code update.[146] The California Energy Commission ultimately adopted a code that included heat pumps as an energy performance standard baseline for water or space heating in all new single-family homes and for space heating in multifamily homes. Though this decision falls short of a fully electric baseline, it is an important move and the first of its kind that encourages the adoption of heat pump technology for space and water heating.[147]

Codes should also be revised to reflect current best practices of ensuring that safety and performance goals are met. For example, the most basic requirement for compartmentalization is usually the "firestopping" provision of the local fire code. Quality control and verification procedures for firestopping rely on visual inspections, which is inadequate to ensure that effective control of air movement has been achieved. Firestopping requirements should be toughened to include instrumented testing after installation, similar to exterior envelopes.

Advocate for Federal Initiatives That Make It Easier to Pursue Deep Carbon Reductions and Beneficial Electrification in Housing

1. Advocate for policies that increase housing resources and dedicate them to decarbonization.

Many existing federal programs currently do not anticipate beneficial electrification. In the absence of explicit affirmation, regulations have been written to implicitly require piecemeal approaches, or financial limits have been set that discourage comprehensive approaches like beneficial electrification. These programs must be adapted to meet the health needs of low-income communities and the seriousness of the climate emergency. They should increase overall investments and require targeted investments for communities that are overburdened and underserved. Significant, targeted investments should be made to address starting-line disparities such as deferred maintenance and housing quality deficiencies.[148]

Additionally, although tax credits and deductions have proven successful in incentivizing the decarbonization of the transportation and energy sectors, they are often insufficient and too complicated to incentivize homeowners and the building industry at large to engage in beneficial electrification. In fact, federally supported low-income housing and low-income households are unable to use a suite of existing tax credits and deductions, meaning improved and targeted tax credits are critically needed to benefit historically disenfranchised communities.[149]

2. Push for initiatives that remove barriers to efficient use of federal resources.

Where federal funds are needed to implement local policy priorities, disjointed or conflicting regulatory requirements can stymie progress. These include rules that prohibit combining certain federal funds or that require local "matching" funds; slow, onerous, and/or opaque approval processes or waiver determinations; and limitations on capital programs that have failed to keep up with evolving best practices in design and delivery of construction projects.[150]

State and local governments should consider the impacts of such "business of government" issues on their ability to pursue beneficial electrification and use the national coalitions and networks at their disposal to seek to change them.

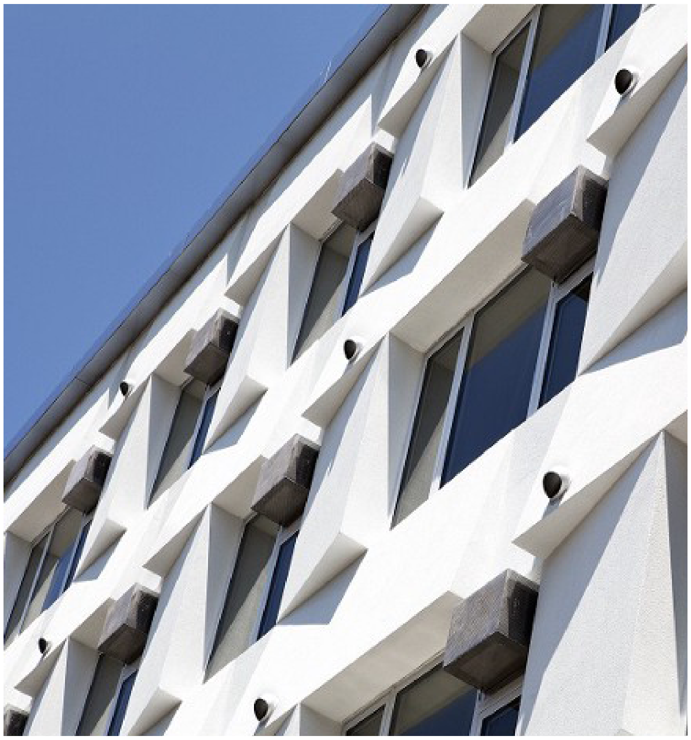
[xiii] Energy recovery ventilation (ERV) is a form of mechanical ventilation that pulls fresh outdoor air into a building while pushing stale indoor air outside, transferring heat and moisture in the process. ERV helps maintain a building's indoor temperature and humidity levels while filtering out air pollutants, boosting HVAC efficiency while improving indoor air quality.

Conclusion

Conclusion

Low-income communities are among the most vulnerable to the impacts of climate change. As the movement toward electrification has gained momentum, the threat of further entrenching disparities has energized environmental justice and climate justice organizations to call for careful consideration of its impact on socioeconomic disparities. The synthesis here, which links health harms to housing quality deficiencies and fossil fuel combustion, shows that beneficial electrification is a necessary step to improve health in low-income communities.

In short, homes must be "built tight and ventilated right," with no fossil fuel combustion. By making explicit the ties between housing, climate, and health, beneficial electrification provides common ground for broad, inclusive coalitions to address historic, current, and potential future inequities while working toward a zero-carbon, healthy future.



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