Centering Energy and Environmental Justice in the Buildings Energy Sector

Ardelia Clarke,[1] Michael Deru,[1] Eric Lockhart,[1] Laura Beshilas,[1] Gokul Paranjothi,[1] Nathan Wiltse,[1] Scott Belding,[1] Roderick Jackson,[1] Nikitha Radhakrishnan,[2] Mariana Egea-Casalduc,[3] Kassandra Grimes,[3] and Billierae Engelman[3]

1 National Renewable Energy Laboratory
2 Pacific Northwest National Laboratory
3 Oak Ridge Institute for Science and Education (ORISE) Fellow for the U.S. Department of Energy

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List of Acronyms

AMI	area median income
BTO	Building Technologies Office
CO_{2e}	carbon dioxide equivalent
DOE	U.S. Department of Energy
FPL	federal poverty level
HVAC	heating, ventilating, and air-conditioning
RDD&D	research, development, demonstration, and deployment
SEEA	Southeast Energy Efficiency Alliance
TEPRI	Texas Energy Poverty Research Institute

Executive Summary

The U.S. Department of Energy (DOE) has an ambitious goal to "accelerate the research, development, demonstration, and deployment of technologies and solutions to equitably transition America to net-zero greenhouse gas emissions economy-wide by no later than 2050" (DOE 2022). The United States' 123.5 million homes and 5.9 million commercial buildings consume 74% of the nation's electricity, 39% of the nation's total energy, and account for 35% of the nation's CO_2 emissions (U.S. Energy Information Administration 2022b; 2022a; 2022c).

The existing built environment and DOE's technology research, development, demonstration, and deployment (RDD&D) activities benefit many, but not all Americans. An unequal distribution of RDD&D benefits has burdened some communities more than others, especially those who are already vulnerable, under-resourced, and disproportionately affected by current and historical energy and social systems. These inequities have produced higher rates of pollution, negative health impacts, and higher energy burdens and energy insecurities in these communities.

When energy use is inhibited due to costs, impacts can extend beyond comfort and convenience to health and safety risks. Energy burden quantifies the economic hardship of energy inequities experienced by a household or business. A household suffers from energy burden if they spend 6% or more of their income on energy costs (Fisher, Sheehan & Colton 2020).[1] The American Council for an Energy-Efficient Economy approximates that 25% of U.S. households are energy burdened (Drehobl, Ross, and Ayala 2020). Energy insecurity, a similar but separate metric, is defined as the inability to meet basic household or business energy needs. In 2020, 34 million households (27% of households) reported experiencing energy insecurity (U.S. Energy Information Administration 2022d).

The impacts of energy burdens and energy insecurity are disproportionately distributed in the United States and experienced mostly by disadvantaged communities (e.g., low-income, majority non-white, small, or rural). These negative impacts are correlated with socioeconomic, racial, and ethnic demographics and/or geography (Lewis, Hernandez, and Geronimus 2020). For example, high energy burdens affect communities of color at disproportionate rates when compared to their white counterparts—Black households have 64% higher energy burden than white households. This trend also occurs in Hispanic households, as they experience a 24% greater median energy burden than white households (Kontokosta, Reina, and BonCzak 2020).

Commercial buildings are also an important and less examined part of this conversation of energy burden and energy insecurity. Small businesses in particular are major economic drivers for the U.S. economy by generating 65% of the net new jobs from 1993 to 2013 in the United States (U.S. Census Bureau et al. 2014). The small business sector consumes more than 40% of the energy used in U.S. commercial buildings and has shown a major opportunity for efficient RDD&D due to the large potential energy savings (U.S. Energy Information Administration 2003). Yet, small commercial buildings (less than 25,000 ft^2) are the hardest building sector to reach with energy efficiency measures, especially those in disadvantaged and rural communities—this is due in part to historical disinvestment and legacies of discriminatory

[1] Energy burden does not include transportation fuel costs (e.g., gasoline or electric vehicle charging)

policies. Small business owners and operators have suffered from energy inequities over the years compared to their larger commercial counterparts. Understanding and quantifying current energy inequities in the commercial building sector is vital to spur innovative decarbonization opportunities and to ensure all commercial buildings and businesses benefit from a just energy transition.

This report demonstrates how energy and environmental justice relate to the building energy sector overall, starting with energy burden and energy insecurity as the primary vehicles. We show how the United States can create a clean and equitable energy transition for all communities by applying an energy and environmental justice lens on RDD&D activities related to building technologies, efficiency, and decarbonization efforts. We explore the many underlying factors that can cause households or businesses to suffer the effects of energy burdens and energy insecurity. We explain factors such as lack of access to efficient and high-performance equipment, historical injustices such as redlining (Mitchell 2018; Richardson et al., n.d.), racially restrictive property covenants (Welsh 2018), the Federal Highway Act of 1956 (Weingroff 1996), and environmental racism (Millar 2021), and examine their connection to energy injustices in the building sector. This report's intended audience is widely identified as practitioners. This encompasses DOE Building Technologies Office personnel, national lab researchers, scientists, and engineers who both design and validate solutions and those who deploy existing and new technologies to stakeholders across national laboratories and communities, academia, public and private industries, and experts at non-profits, and community-based organizations. The common focus of all these stakeholders is serving occupants and business owners in disadvantaged communities (DOE 2023).[2]

As we progress toward climate goals and move to modernize our energy systems, understanding why the existing built environment has an unequal distribution of benefits and burdens will allow us to apply and create far-reaching, equitable changes to the status quo of building RDD&D processes. Tailoring new technologies to those who have historically not received benefits enables disadvantaged communities to benefit from the clean energy transition while spurring innovative solutions. Understanding the historical inequities disadvantaged communities face will also allow the building energy sector to develop tailored solutions that support the needs of individual communities while gaining technology versatility for deployment at a greater scale. Prioritizing approaches to deliver building technology RDD&D benefits to disadvantaged communities and businesses early in the process ensures outcomes will have broad market impact and appeal rather than limiting market adoption to affluent early adopters.

[2] According to DOE's Office of Economic Impact and Diversity, disadvantaged communities are "communities that experience disproportionately high and adverse economic, human health, climate-related, environmental, and other cumulative impacts."

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1 Introduction

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) has an ambitious mission to "accelerate the research, development, demonstration, and deployment [RDD&D] of technologies and solutions to equitably transition America to net-zero greenhouse gas emissions economy-wide by no later than 2050, and ensure the clean energy economy benefits all Americans, creating good paying jobs for the American people—especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution" (DOE 2022). This goal is complemented by recent White House Executive Orders that build on a "whole-of-government effort to confront longstanding environmental injustices and inequities" (The White House 2023). However, current business-as-usual approaches to a clean energy economy could yield outcomes that are at odds with EERE's mission of equitable access to renewable energy and its benefits for all. Recognizing historical and current inequities suffered by disadvantaged communities (e.g., low-income, people of color) concerning social, economic, and energy systems, will support a safe, resilient, affordable, healthy, equitable, and just energy transition.

The Justice40 Initiative enables an equitable energy transition as a government effort to ensure that at least 40% of the total benefits from federal investments in climate and clean energy go to disadvantaged communities (Executive Office of the President 2021; The White House 2021). Justice40 addresses elements of distributive and restorative justice (defined in Section 3.3) by directing benefits to historically marginalized, overburdened, and disadvantaged communities and addresses structural and procedural justice by requiring practitioners to consider, involve, consult, and engage disadvantaged communities in program design and policy decision-making. Designing DOE programs to decrease the energy burden in disadvantaged communities represents a major opportunity to complement and support implementation of the Justice40 Initiative. To achieve this within building technology programs in particular, this report discusses and applies an energy and environmental justice lens to understand the barriers to a just energy transition for residential households and commercial businesses within disadvantaged communities.

Energy justice is an emerging concept that is pivotal to achieving DOE's ambitious goals. This report focuses on how energy justice relates to residential households and commercial businesses in urban and rural communities across the United States that experience disadvantages (e.g., low income; high poverty; high energy use or cost; transportation and/or housing burden). Throughout this report, the term "disadvantaged communities" aligns with DOE mission goals and represents those historically harmed by the energy system (Office of Economic Impact and Diversity 2022). As a preliminary framework, this report integrates an energy and environmental justice lens across the Building Technologies Office's (BTO's) RDD&D portfolio to provide insights into current barriers to building solutions for disadvantaged communities. We introduce the unique role of the DOE's national laboratory system, RDD&D, and its impact on equitably decarbonizing our energy system. We explore the state of energy and housing burden and energy insecurity in the United States, as the primary vehicles, to understand the past and present energy inequities faced by disadvantaged communities. We also discuss how to ensure that decarbonization efforts do not exacerbate historical, existing, or create new inequities, yet are equitably tailored to the needs and burdens of all communities within the United States.

2 Equitable Decarbonization and the Role of National Laboratories

The establishment of DOE via the Department of Energy Organization Act of 1977 fundamentally modified the role of the federal government in the energy sector (DOE 1994). As a result, DOE became responsible for energy conservation, nuclear weapons, regulatory and centralized energy data collection and analysis programs, and long-term, high-risk research and development of energy technologies and solutions. These complex challenges were associated with global geopolitical conflicts, beginning with World War II, and were addressed through strategic investments to create 17 unique national laboratories across the United States. Each national laboratory has distinct but complementary capabilities that span a multitude of topical research areas from mathematics, chemistry, biology, physics, material science, and computational science to information sciences, public health and policy, biomedicine, and communications.

The core function of the national laboratories, as hubs of innovation, is achieved via two parts: (1) cultivation of a pipeline of high-caliber scientists, engineers, and support personnel and (2) research, development, demonstration, and deployment (RDD&D) processes to transition high-risk solutions from early stages of research and development (R&D) to commercialization and deployment. Both aspects are critical to ensure national laboratories maintain their innovative edge in addressing new challenges and essential global needs.

Multidisciplinary teams of national laboratory experts collaborate often with experts from universities, businesses, nonprofits, utilities, and other public and private industries. Students and professionals are also centered in the pipeline via the RDD&D process. Such scientific collaboration through the RDD&D process, thus far, has yielded the national laboratory complex 118 Nobel Prizes and led to the discovery of 22 new elements on the periodic table.

The purpose and outcomes of the national laboratories' RDD&D process have evolved based on the nation's need to solve complex scientific challenges. Traditionally, the research and development process at the national laboratories has been focused on finding the best scientific solutions to complex problems. Until recently, only a small portion of DOE's funding and mission was focused on developing solutions to consumer problems.

Now, to achieve DOE's ambitious climate goals by 2050, the United States has an opportunity to "confront longstanding environmental injustices and inequities" (The White House 2023). By developing programs, policies, and activities centered on energy and environmental justice, such as Justice40, federal agencies can start to advance toward equitable decarbonization that reduces disproportionate climate, health, environmental, and other cumulative impacts on disadvantaged communities.

National laboratories are uniquely positioned to advance equitable decarbonization by addressing and reversing inequities in technology access and adoption via inclusive RDD&D practices. Centering disadvantaged populations and businesses in the research, design, validation, and deployment of programs, projects, policies, and practices helps ensure that the outcomes of the national laboratories' technology commercialization process include those historically excluded communities. Through DOE funding and guidance, national laboratories can continue to lead the nation's research enterprise, ensuring technologies and solutions are truly ready off the shelf for adoption and address the needs of all U.S. communities.

3 Energy and Environmental Justice in Buildings

3.1 Energy Justice

There are many nuanced definitions of energy justice; this report uses the definition summarized effectively by the Initiative for Energy Justice (Baker, DeVar, and Prakash 2019):

Energy justice refers to the goal of achieving equity in both the social and economic participation in the energy system, while also remediating social, economic, and health burdens on those historically harmed by the energy system ("frontline communities").

The authors agreed on this definition for consistency with established practice in research, academia, activism, and policymaking. Energy justice is intended to be synonymous with energy equity and social justice. Other terms related to environmental justice will be used as needed and defined in context each time.

3.2 Environmental Justice

Environmental justice, according to the U.S. Environmental Protection Agency (2022), is the "fair treatment and meaningful involvement of all people… with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." Environmental justice often references frontline communities (communities "on the front lines" of climate change and societal inequities) because they are directly impacted by climate change and environmental hazards at higher rates (State of Vermont 2021). Examples include communities where neighborhoods are more prone to flooding or pollution and receive less funds to recover from extreme climate events. This report considers frontline communities to be part of the larger umbrella of disadvantaged communities.

Energy justice is closely interconnected with environmental justice. Frontline communities are disproportionately impacted by environmental harms associated with fossil fuel reliance in the current energy system and would benefit greatly from an equitable energy transition. This is achieved through meaningful involvement with disadvantaged communities at the onset of the design and development of a solution to the deployment, installation, and maintenance of that solution in disadvantaged communities. Ensuring that these communities are deeply involved in a just energy transition via procedural justice can be considered a facet of environmental justice (Baker, DeVar, and Prakash 2019). Many topics discussed in this report could be categorized as both an environmental justice issue and an energy justice issue (e.g., urban heat islands in Section 6.3.1). For this report, the authors focus on the energy justice facets of the topics and the interplay between energy justice and buildings.

3.3 Intersectionality of Energy Justice and Buildings

Energy justice has multiple dimensions, each describing different ways in which disadvantaged communities are disenfranchised by social, economic, racial, and health inequities caused by policy decisions and reflected and manifested in the U.S. energy system. This section explains different types of energy justice, with examples and situations showing how each dimension of energy justice could be implemented into the building decarbonization and energy efficiency RDD&D portfolio for a just energy transition. These examples illustrate the complex connections between building conditions, energy transitions, and impacts on the lives of people that should warrant considerations for building technology RDD&D.

Distributive justice describes fairness in the allocation (i.e., distribution) of costs and benefits that arise from energy development (Rawls 1971; Lamont and Favor, n.d.). If a program deploys grid-interactive efficient building technologies, for example, resulting in a disproportionately low number of those buildings in disadvantaged communities, then the people in those communities do not receive the same benefits from the investment in building technologies as others in more affluent areas. Furthermore, the adoption of renewable energy and energy efficiency technologies may shift additional utility operation and maintenance costs onto an ever smaller pool of building occupants left behind in the technology transition (Alexander McGee and Trent Greiner 2019). Members of disadvantaged communities would then be subject to both fewer benefits and greater costs than others, exacerbating inequality and harming the long-term potential for energy transitions. The lens of distributive justice helps identify pathways to more equitable distributions of these costs and benefits.

Procedural justice in energy explains how disadvantaged communities are party (or not) to the decision-making processes and procedures that result in access to building decarbonization, energy efficiency technologies, and associated benefits (Greenberg 1986; Folger 1987; Lind and Tyler 1988). There are three mechanisms to describe inclusion in the decision-making process: achieving just outcomes through seeking and utilizing local knowledge from affected communities, increasing institutional representation, and higher information disclosure (Jenkins et al. 2016). Oftentimes, even when disadvantaged communities are the targeted recipients of improvements to the built environment, they are not included in the design and delivery of the project's presumed benefits. To ensure community buy-in, the following must be achieved: (1) a program's benefits must be determined and valued by the recipients, (2) disadvantaged communities must be set up for long-term success, and (3) program managers must actively engage with trusted community-based organizations for impactful participation in shaping policymaking and program design. This inclusion covers everything from energy efficiency programs to climate action planning and setting building technology research agendas.

Recognition justice acknowledges the extent to which disadvantaged communities have been affected by technology development and deployment in energy and buildings and looks beyond individual use cases to how a given community might access different buildings or the broader built environment. For example, energy burden (see Section 4) may be one stressor among several in a disadvantaged community (Brown et al., n.d.). Households may also lack efficient devices, have an increased likelihood of utility service disconnection due to payment delinquency, and/or be in a neighborhood with underfunded public facilities (e.g., library or community center) that do not offer an effective place for residents to cool off. Recognition justice sheds light on these stacked and interrelated consequences of building and energy decisions, which are necessary for understanding and respecting the living conditions of building occupants.

Restorative justice redresses the harm associated with energy-related building issues. Energy burden, energy insecurity, proximity to pollution (Kioumourtzoglou et al. 2016) (Reichmuth

2019), and exclusionary housing policies (Nardone et al. 2020) are historical examples of disproportionate and systemic injustices placed on certain communities, placing them at a disadvantage in the energy system. Applied to building technologies, restorative justice seeks to ameliorate the present and past harms caused by these practices, meaning that the challenges and adverse health effects of disadvantaged communities are prioritized during the clean energy transition. Restorative justice in the building sector also ensures the next generation of renewable energy workers and company owners are diverse, thereby creating wealth where it hasn't been centered traditionally in the past.

4 Energy Burden and Energy Insecurity

In the United States, energy drives the economy and touches every aspect of our lives (Brown et al., n.d.). We use energy to prepare food, access drinking water, receive information (e.g., television, phone, internet services), heat and cool our homes and businesses, maintain safe food and medicine, transport products and people (CISA 2023), and make the goods we use every day (Hernandez and Bird 2012; U.S. EIA, n.d.). When access to energy is inhibited for any reason, the burden can be felt in every facet of life. The cost burden related to energy or utility costs is inextricably linked with the burden associated with housing costs (American Community Survey 2018).

4.1 Energy Burden

Energy burden refers to the percentage of a household's gross annual income spent on energy costs (including electricity, natural gas, and other home-heating fuels, but not including energy required for transportation) (Lewis, Hernandez, and Geronimus 2020). Households are considered energy burdened if they spend 6% or more of their annual income on energy costs (Fisher, Sheehan & Colton 2020), and energy bills are deemed unaffordable if households are energy burdened. This can be quantified by the energy affordability gap, which measures the amount households spend on energy over the 6% affordable limit (U.S. Department of Housing and Urban Development 2008). A recent study by the American Council for an Energy-Efficient Economy approximates that 25% of U.S. households are energy burdened (Drehobl, Ross, and Ayala 2020). While these statistics are significant, the real impact may be higher due to limitations in data (e.g., housing cost burden was not included). These estimates also do not include households that do not directly pay for energy. In addition, the estimate is based on a small sample size with known biases within census data and may not fairly represent all communities (Rothbaum et al. 2021; Biemer and Peytchev 2013). Further regional studies (e.g., rural, tribal) coupled with sociodemographic factors are needed for a more representative sample of the current state of energy burden in the United States.

The energy burden metric encapsulates the cumulative impact of inequitable legacies of policy and RDD&D decisions and is highly intertwined with the burden of housing costs (Schott 2022). Housing cost burden or rent burden is defined as spending more than 30% of monthly income on housing costs including energy (or utility bills). Households are severely rent burdened if they spend more than 50% (U.S. Department of Housing and Urban Development (HUD) 2018). Nationwide, the United States is in a major housing crisis: A 2019 study found that 47% of the 44 million renter U.S. households were rent burdened (Landis and Reina 2019; Collinson 2011; Landis and Reina 2019; Collinson 2011). In addition, the American Community Survey estimated that 40.6% of rental unit residents suffer from rent burden. Therefore, a household paying 6% or more of their income on energy costs is likely to also be suffering from rent burden (American Community Survey 2018). A household suffering from rent burden that cannot afford utility bills, even if low, can be evicted for not paying utility bills. It is worth noting that the cost burden associated with transportation is also a factor in energy burden but is out of the scope of this report.

Energy burden can also be affected by regulatory decisions and utility rates that disproportionately impact costs to specific users. For example, all taxpayers contribute to new utility programs that emphasize new technologies, programs, and incentives (e.g., electric vehicles, photovoltaic generation), yet affluent communities predominately benefit from these utility programs. So, those who don't receive these benefits still pay slightly more in utility costs for new programs that don't benefit them. Similarly, energy burden may be exacerbated and only solved partially through energy and building RDD&D efforts without policy and regulatory change due to additional factors listed below:

1. Rates and cost recovery (e.g., fixed delivery charges penalize low-usage customers and raise bills for those who can least afford the increase, like low- to moderate-income households, or seniors) (Whited, Woolf, and Daniel 2016).

2. Decision-making power of state energy regulators via integrated resource plans to choose the mixture of resources and materials used in communities for energy generation and delivery (SEE Action 2011).

3. Variable/time-of-use utility rates that only benefit those with load management capabilities.

Energy burden can exist across the income spectrum, but households with lower incomes are encumbered the most. A national study found that households that make $15,000 or less per year spend on average 21% of their income on utilities. Anyone with a large and leaky home can attest to large energy bills, but those with more discretionary income can better shoulder those costs without trading off other necessities (Carliner 2013). Energy burden does not account for those who go without energy services because they are energy insecure and cannot afford it (see Section 4.2: Energy Insecurity). The average amount of income spent on energy costs can also vary based on the region and location of one's home or business. Recent studies investigated the energy burden of households in the Alabama Black Belt and South Texas due to the high percentage of low-income households and populations of Black, Indigenous, and people of color per census block group (SEEA and TEPRI 2021). The average energy burden for all households in the Alabama Black Belt was 9.9%, with $2,575 spent on average on annual energy costs (SEEA 2021).

Energy burden has been widely studied for residential buildings, yet very little has been explored for commercial buildings. Many small and/or minority business owners struggle to pay for energy, equipment replacements, and efficiency upgrades (see Section 5.3: Small and Minority Businesses). One study of small businesses found that energy costs were a significant burden at least some of the time for more than half of the respondents (The City of Rolla 2021). A 2011 study by the National Small Business Association found that 52% of small businesses were concerned about the future of energy costs, and 40% cited cash flow as the primary obstacle to pursuing energy efficiency measures. Furthermore, this same study found that the top three ways businesses manage energy burden were to increase prices, reduce business travel, and reduce workforce. Energy-burdened businesses forced to increase prices or reduce services will not be as competitive or as successful as businesses that are not energy burdened (National Small Business Association 2011). Also, businesses forced to shrink their workforce due to energy costs further harm local workers once gainfully employed, continuing the cycle of cost burdens at the household level.

4.2 Energy Insecurity

Energy insecurity (or poverty) is the second vehicle by which an energy and environmental justice lens can be applied to the building energy sector. Traditionally, energy insecurity is defined as the inability to meet basic household or business energy needs. Energy insecurity is multidimensional and characterized by energy-related inequities such as (Hernandez 2016; Lewis, Hernandez, and Geronimus 2020):

1. **Economic** hardship (e.g., inability to pay for utility services).

2. **Physical** hardship (e.g., deficiencies in buildings that negatively affect comfort and energy efficiency).

3. **Behavioral** strategies for managing energy consumption (e.g., using stove/oven for heat).

4. **Financial** trade-offs, such as leveraging medical vulnerabilities to avoid utility shut-off, lead to high coping and health hazards and are more prevalent in Black communities due to discriminatory housing and financing policies (Geronimus et al. 2006).

Energy insecurity statistics were reported by the U.S. Energy Information Administration in 2015 and 2020 based on five situations self-reported by survey households: (1) reduced or went without necessities to pay energy bill, (2) received a disconnection notice, (3) kept home at unhealthy or unsafe temperatures (Figure 1), and (4) unable to use heating or (5) air-conditioning equipment (EIA 2022).

In 2015, 37 million households (31% of all U.S. households) experienced energy insecurity, and in 2020, 34 million households (27% of households) reported experiencing energy insecurity (Figure 1). This 4% overall reduction was driven by the federal moratorium placed on state utility shut-offs, as 3.4 million U.S. households did not receive a disconnection notice during the coronavirus pandemic in late 2020 that would have without the moratorium. Similarly, there was a slight reduction (2%) in households that kept their home at unhealthy or unsafe temperatures, yet households still reported that they were unable to use their heating (5 million U.S. households) or air-conditioning equipment (6 million U.S. households) due to the inability to afford repairs or fuel. It was found that 1.4 million households in 2020 had someone seek medical attention due to the unsafe temperature of their homes.

Though any household or business can experience energy insecurity, Figure 2 illustrates the difference in experience by residential housing tenure for the total number of U.S. rental-occupied (40.6 million) and owner-occupied (82.9 million) households reported in 2020 (U.S.

Energy Information Administration 2022c). It was found that 41% of rental households reported some form of energy insecurity in 2020, versus 20% of owner-occupied households. Similarly, rental households are twice as likely to suffer from energy insecurity by forgoing food or medicine, leaving the home at an unsafe temperature, and receiving a disconnection notice than owner-occupied households (Figure 2).

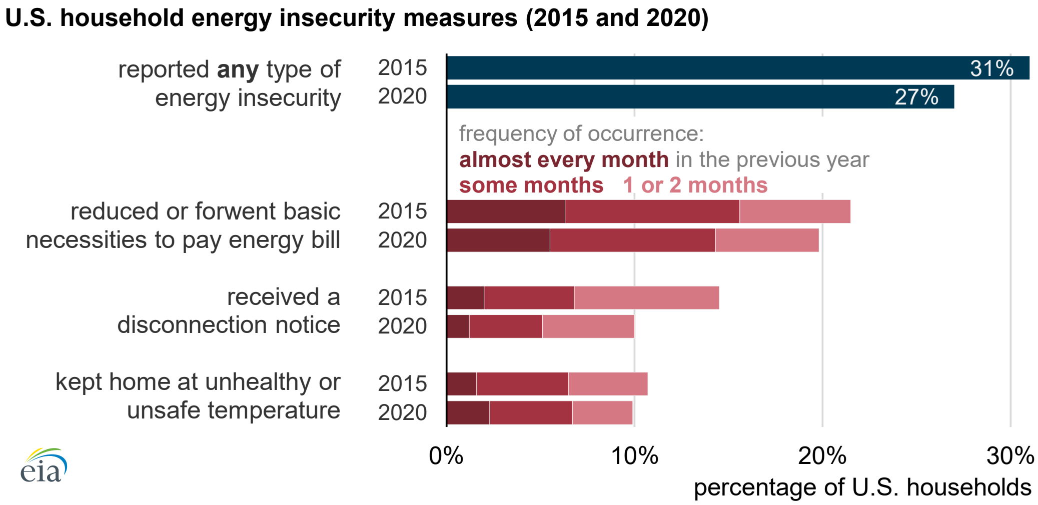

Figure 1. U.S. households in 2015 and 2020 that reported energy-insecure situations, for what reason, and time duration of scenario

Figure from U.S. Energy Information Administration (2022)

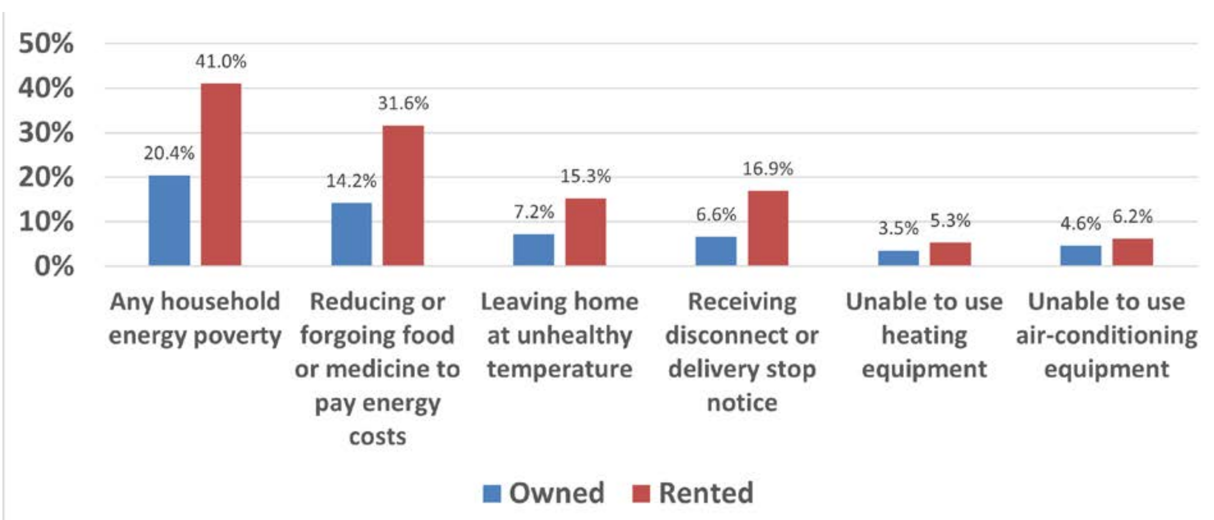

Figure 2. U.S. households in 2020 that reported energy-insecure situations based on housing tenure

Data from U.S. Energy Information Administration (2022)

Because energy insecurity is multidimensional, different forms of hardship can occur or not occur within the same household. A business or household can have a physical hardship such as inefficient or unreliable heating and cooling systems and power outages. For example, Alaska residents who cannot afford the cost of heating oil (a 66% increase between 2007 and 2014) must burn wood for affordable space heating despite the negative health impacts. Similarly, some residents in South Carolina reported taking multiple $25 online surveys to have enough money for canned food and to afford utility bills (Murkowski and Scott 2014). These households are suffering from a form of energy insecurity as an economic hardship even though they can pay their utility bills on time. A household that has to choose between paying utility bills or other bills experiences energy insecurity in a different way than a household that puts on extra sweaters in the winter to use less energy for heating, but both experience energy insecurity (Lewis, Hernandez, and Geronimus 2020; Hernandez and Bird 2012).

Energy insecurity is not well documented for commercial buildings, yet it is a vital lens to address the barriers business or property owners face due to energy-related costs. A business or property owner may suffer from energy insecurity if they are unable to afford regular maintenance and repairs on heating, ventilating, and air-conditioning (HVAC) systems and water heating systems, or if they are unable to replace a failed system. The inability to replace a failed HVAC system can be doubly problematic if the business must shut down or reduce services and lose income.

Energy insecurity is known to result in negative health and safety consequences. For example, residents impacted by energy insecurity may use malfunctioning space heaters to survive during winter months, sometimes resulting in the risk of deadly building fires. Or, as described previously, residents may spend their limited funds on energy instead of critical medications, which can lead to severe medical outcomes. As incidences of extreme weather events increase, there is a dire need for equitable distribution of energy-efficient and resilient building technologies to avoid the need to make economic, physical, behavioral, and or financial tradeoffs in decision-making that could result in tragic accidents (Maldonado and Aponte 2022). The next section dives deeper into the intersectionality of energy burden, energy insecurity for residential and commercial buildings, and who is most impacted by these inequities.

5 Who Is Impacted by Energy Burden and Energy Insecurity?

The impacts of energy burden and energy insecurity are disproportionately distributed in the United States and are experienced mostly by disadvantaged communities. These negative impacts may be exacerbated based on socioeconomic, racial, and ethnic underpinnings, and/or geographic characteristics (Lewis, Hernandez, and Geronimus 2020):

- **Socioeconomic**: low-income, renters vs. homeowners, business owner vs. type of business owner (e.g., minority, women, veteran).
- **Racial and ethnic**: Black, Hispanic, Asian American, Pacific Islander, Native American, and other Indigenous people.
- **Geography**: urban vs. suburban vs. rural.

The role these additional underlying characteristics have on residential households and commercial businesses within disadvantaged communities is explained further in this section. Each subsection includes a table that provides an overview of the barriers that residential households and commercial businesses face in reducing their energy burden, as well as how these barriers relate to energy justice in buildings RDD&D. For example, the percentage of energy insecurity experienced by U.S. households varies based on other factors than housing tenure, such as census region; number of children present in household; and race, ethnicity, and income of household (Table 3) (EIA 2022). Previous research by the Southeast Energy Efficiency Alliance (SEEA) and Texas Energy Poverty Research Institute (TEPRI) demonstrates the relationship between energy insecurity and energy inequities based on different residential building types in the U.S. South and Texas, specifically. Buildings in the South are highly underinvested, as 53% of all residential buildings were built before mandated energy codes (minimum standards required for U.S. builders to meet for efficiency and comfort). Georgia, for example, has a high frequency of housing stock that was built more than six decades ago (SEEA and TEPRI 2021).

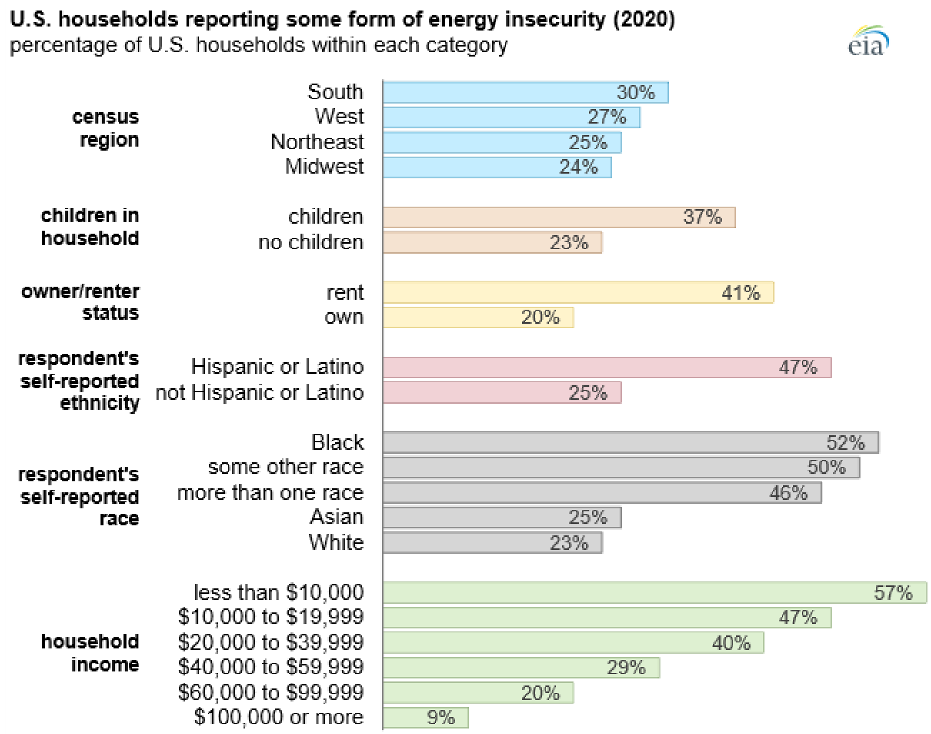

Figure 3. U.S. households (18,496 households) in 2020 who reported energy-insecure situations based on their region, number of children, owner/renter status, racial and ethnic, and income information

Figure from U.S. Energy Information Administration (2022)

While researchers have made important strides to quantify energy burden and energy insecurity on a macro and regional scale, city planners and policymakers lack granular data at a high spatial and temporal resolution needed to develop effective policies and programs to directly address energy and non-energy inequities at the neighborhood level. Building-related proactive policies that are sensitive to local needs could consist of incentives and mandates for energy efficiency improvements based on measured energy performance or subsidies for energy retrofits tied to building characteristics for minority households. By coupling an energy and environmental justice lens with data analysis of buildings RDD&D, we can start to apply a lens of restorative justice to remediate such inequities.

5.1 Low- and Moderate-Income Households

There are two common criteria used by federal assistance programs to classify whether a household is considered low income: federal poverty level (FPL)[3] and area median income (AMI). Low-income households tend to live in poor-quality, less energy-efficient infrastructure (Abrahamse and Steg 2011). This lack of quality infrastructure has implications for the energy use of these residents and business owners. Research conducted by SEEA and TEPRI suggests low- to moderate-income households have either a range of 0%–80% AMI or have an income ≤200% below the FPL (SEEA and TEPRI 2021). Low-income households tend to spend from 10% (Baxter 1998) to 20% or more on energy expenditures (Kaiser and Pulsipher 2006).

Regionally, low-income households could spend more per month on utility costs due to historical underinvestment in demand-side energy efficiency measures from poorly insulated and weatherized buildings and a lack of high-efficiency appliances to offset such costs. Despite the lowest residential electric rates (11–12 cents per kilowatt-hour), the South has the second highest average residential bills, ranging from $127 to $138 per month, which disproportionately impacts low-income households and communities of color (SEEA 2021). Since 2009, low- to moderate-income households in communities of color across Southern states like Texas are leading the United States in the largest number of residents residing in mobile and older manufactured homes. Built before 1976, these unregulated homes historically have been the sole affordable housing option for disadvantaged communities due to historical and systemic racial discrimination (see Section 4). Therefore, removing these homes is inequitable, yet options could be considered to make low-cost manufactured housing more energy efficient. These unregulated manufactured homes emit greenhouse gas emissions on the scale of 132 to 189 million pounds of carbon dioxide equivalent (CO_{2e}) annually, despite housing tenure (Bryant 2021). Furthermore, households in one-unit single-family and manufactured homes have an average energy burden of 20% (SEEA and TEPRI 2021).

Introducing an energy justice lens via energy burden can provide an additional viewpoint into the energy inequities that low-income households face in the United States. Across the country, there is a higher prevalence of energy burden in extremely low- to moderate-income households (0%–300% of the FPL) when compared to higher-income households (≥400% of the FPL). For extremely low-income households (0 to 100% of the FPL), Figure 4 shows the average energy burden at the census tract level is 14% for renter-occupied and 19% for owner-occupied, compared to 3% energy burden for moderate-income households (200%–300% of the FPL). Renter-occupied and owner-occupied households across all FPLs spent more of their income (i.e., higher energy burden) on electricity than natural gas (Table 4) (Ma et al. 2019).

Figure 4 also demonstrates that the percentage of the population that identifies as Black or African American is higher in renter-occupied households at 21%, compared to 12% in owner-occupied households. It must be noted that Figure 4's energy burden calculations cannot be joined with the demographic information despite the same geographic resolution (e.g., census

[3] The Department of Health and Human Services defines the FPL as an economic measure that quantifies the annual income earned by a household or the percentage of people living at or below the poverty level. The FPL is updated annually and has different distributions based on age, sex, location, ethnicity, and level of income inequality (Hayes and Boyle 2022).

tract level), because energy burden data is aggregated to the household level and demographic information is at the individual level. For example, Figure 4 does not state that 9% of the population that self-identifies as Black for owner-occupied households (150%-200% FPL) also has an electricity and gas energy burden of 8%. Rather, Figure 4 states both statistics independently of each other. Further analysis should investigate how energy burden statistics directly vary for different demographic groups and ownership status at the same aggregation level. It should also be noted that the average energy costs for homeowners in the lowest income bracket are approximately 30% higher than the average energy costs for renters, which explains some of the higher energy burden for homeowners. Therefore, pathways to make electricity more cost-effective will be vital as DOE advances decarbonization.

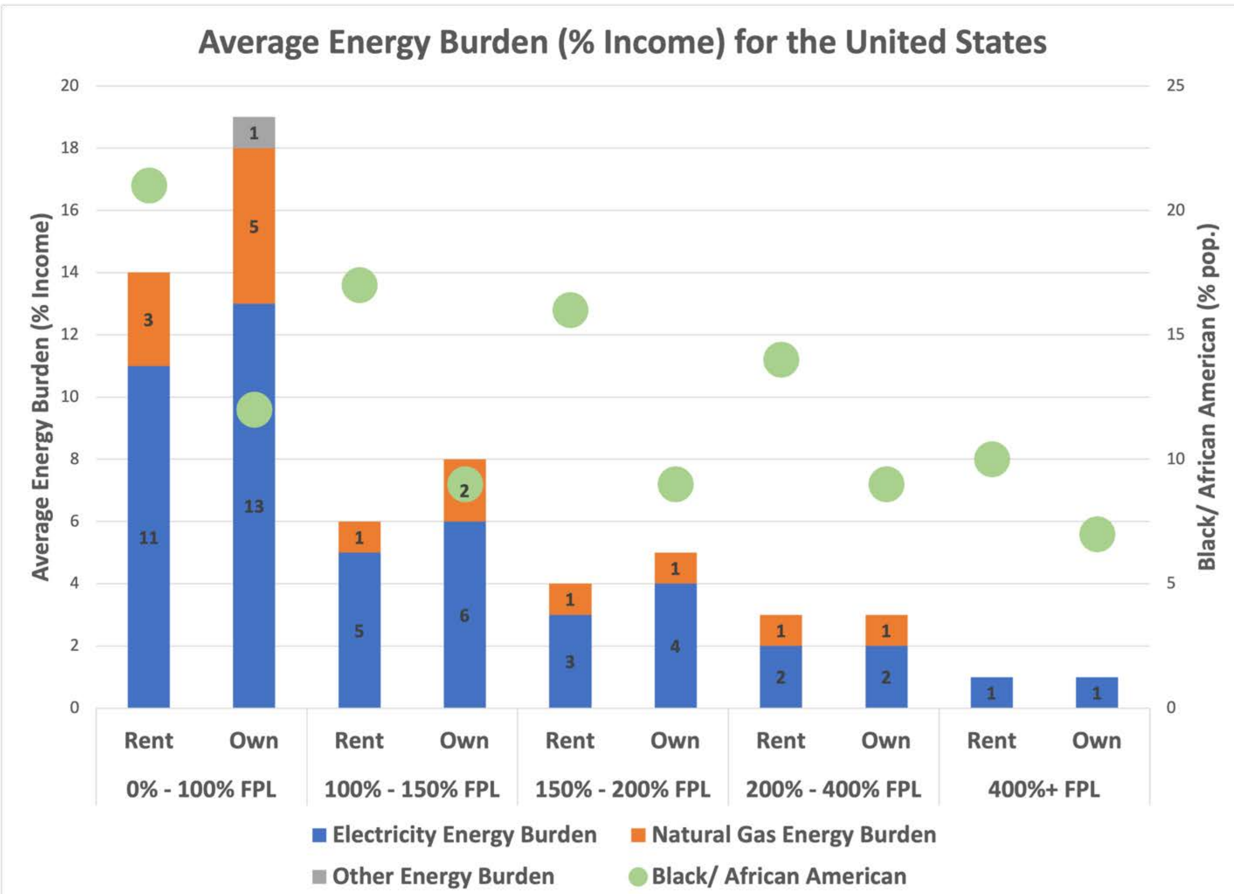

Figure 4. Average energy burden for the United States based on FPL, renter-/owner-occupied, and energy source using DOE's Low-Income Energy Affordability Data (LEAD) tool.

Data from Ma et al. (2019)

Disadvantaged households and businesses could greatly benefit from adopting energy efficiency technologies that reduce suffering from energy burden and energy insecurity (NYSERDA 2021; California Energy Commission 2016). Support for these households suffering from energy insecurity and facing utility disconnections cannot come from existing energy assistance programs alone (Bryant 2021). For low-income households, low-cost energy improvements could reduce energy costs by as much as $1,500 per year (Kontokosta, Reina, and BonCzak 2020). Looking at a specific example in Minnesota, we multiply the potential dollars saved annually ($1,500) via a reduction in energy costs by those 375,000 eligible Minnesota households that did not receive Low Income Home Energy Assistance Program assistance (Table 1). This equates to $563 million of energy savings if energy efficiency measures were adopted and deployed in these households that are currently excluded from financial assistance programs.

Unfortunately, there are many barriers to lowering the energy burdens and improving the energy conditions of low-income households. Table 1 provides a summary of the primary barriers and associated energy justice considerations for buildings' RDD&D activities.

Table 1. Barriers to Decreasing Energy Burden Experienced by Low-Income Households and Relationship to Energy Justice in Buildings RDD&D

Barrier for Low-Income Households	Energy Justice Considerations in Buildings RDD&D
Criteria for FPL and AMI	Households that meet the FPL or AMI criteria for assistance programs may not receive financial assistance, and other households may not qualify for FPL- or AMI-based assistance but still be energy burdened. In Minnesota, 75% of eligible households did not receive financial assistance from the low-income energy assistance program despite meeting the state's income requirements (Citizens Utility Board of Minnesota 2021).
Split incentive	The motivation for investing in energy efficiency depends on who pays the energy bills. If renters pay for utilities, property owners are not incentivized to invest in energy efficiency measures. If property owners pay energy bills, the renters do not have an incentive to reduce energy use. Split incentives result in higher energy burdens for renter households than homeowning households (Bird and Hernandez 2012). On the energy supply side, decoupling the profits utilities gain from selling energy is complicated. Selling more energy motivates utility companies against promoting energy efficiency. Decoupling regulation may not necessarily be a good fit for low-income tenants and owners who are less likely to participate in utility incentive programs due to barriers such as time, awareness, and access (ACEEE 2021).
Energy efficiency technology access and awareness	Energy efficiency technologies can be expensive, complicated to obtain and install, or not compatible with all households, often making upgrades to more efficient technologies inaccessible for low-income households. These technologies are not tailored to the condition of the buildings in disadvantaged communities; rather, they are tailored to larger, newer, owner-operated buildings with the capital access to adopt energy-efficient technologies (Andrews and Krogmann 2009). To mitigate exacerbating these types of inequities, seeking knowledge from local and trusted community-based organizations during the inception, creation, design, near-term and long-term delivery of building energy efficiency technologies can enable more equitable technology access and further procedural justice.
Low-cost and affordable capital access	Low-income households have a smaller accumulation of wealth and poor access to capital for home improvements (Herbert and Belsky 2006). Some low-income households can access capital, but it's in the form of small-dollar credit products like high-interest credit cards or payday, direct deposit advance, and/or pawn loans. Levy and Sledge (2012) reported that the top three uses for small-dollar credit products are: utility bills (36%), general living expenses (34%), and rent (18%). Similarly, small-dollar credit customers reported experiencing shortage in income due to:

Barrier for Low-Income Households	Energy Justice Considerations in Buildings RDD&D
	a. Living expenses consistently more than income b. Bill or payment due before paycheck c. Unexpected events such as emergency expenses or income drops. As a solution to survive, 40% of small-dollar credit consumers reported going without something they need to address their shortage in income. 20% of low-income residents suffer from energy insecurity and decide between paying for energy or other necessities (food, medicine) (Levy and Sledge 2012).
Low-quality infrastructure due to deferred maintenance	Low-income households often live in poor-quality, less energy-efficient buildings that may be more difficult and expensive to upgrade with high-efficiency technology designed for current conditions (Reames 2016; Lewis, Hernandez, and Geronimus 2020).

5.2 Minority Households

High energy burdens adversely impact households and communities of color at disproportionate rates when compared to white households, regardless of income level. Studies summarized in the Energy Justice Considerations column of Table 2 provide additional insight into the disaggregation of energy costs between white, Black, and Hispanic households as racial and ethnic identifiers.

Black households are twice as likely to report being behind on utility payments and three times more likely to experience utility disconnections (Logan and Stults 2011). A survey in Detroit, a highly segregated city with a majority Black and Hispanic population, found that 50% of respondents reported experiencing a type of material hardship such as employment instability, financial problems, housing instability, food insecurity, and forgone medical care. In Atlanta, the median energy cost burden for Black households is 32% higher than for white households, and for Hispanic households, it is 52% higher than for white households (Bryant 2021).

For Black people, economic hardship is likely bundled with and exacerbated by other hardships such as food insecurity and housing insecurity. This is described as the “trifecta of insecurity” (Hernandez 2013). It is important to view the range of challenges and include these metrics while investigating and developing solutions for the inequities experienced by different communities of color. If programs and incentives for minority communities are designed without a racial and ethnic, or geographic component, then we will not be advancing the restorative justice component of the Justice40 Initiative.

Minority households often have cumulative hardships that impede having adequate economic resources to pursue clean energy efficiency technologies and solutions. Income inequality alone does not explain the pervasive present-day wealth and racial gap that hinders minority households from being able to afford the upfront and maintenance costs of clean energy technologies.

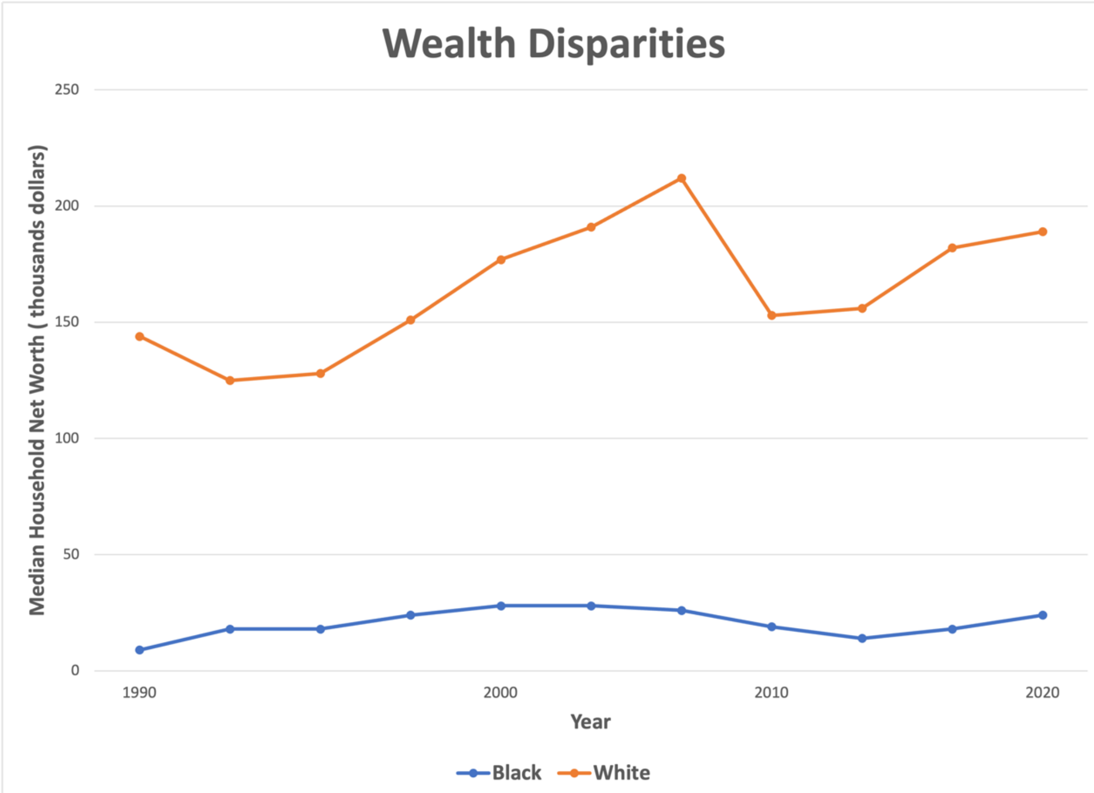

Figure 5. Disparities of median net worth between white and Black households in the United States

Data from RAND Corporation (Welburn et al. 2022)

Table 2. Barriers to Decreasing Energy Burden Experienced by Minority Households and Relationship to Energy Justice in Buildings RDD&D

Barriers for Minority Households	Energy Justice Considerations in Buildings RDD&D
Income inequality	(Bhutta et al. 2020) reported on average minority households such as Black, Hispanic, and "other" or "multiple race" households ("other" includes those identifying as Asian, Alaska Native, Native Hawaiian, Indigenous, Pacific Islander, and more). All groups have lower income thresholds than white households, which have the highest level of both median and mean family wealth: $188,200 and $983,400. Black families' median and mean wealth is less than 15% of white households, at $24,100 and $142,500, respectively (Bhutta et al. 2020). Income inequality is further exacerbated for Black households because they contribute a higher percentage of their household's income to energy bills than any other racial and ethnic group (Karger 2007) (for further details see Section 4). Income inequality also exists among different minority households despite not being designated as low-income. Black and Hispanic families have considerably less wealth than white households and Asian American households. Bhutta et al. (2020) indicate that Hispanic households have a 24% greater median energy burden than white households, though they pay lower utility bills, on average, than Black and white households.

Barriers for Minority Households	Energy Justice Considerations in Buildings RDD&D
Employment in the informal economy	In a survey of 55 African American men and women, 29% stated they are employed by companies in the informal economy (e.g., restaurants, cleaning, retail sales); 71% are self-employed and operate their own business informally (e.g., home repair, landscaping, hairstyling). Both groups are paid in cash, personal check, or unregistered; this may make it more difficult for these minority households to qualify for FPL- or AMI-based assistance programs and prove their income or access to capital through traditional lending due to lack of credit history and/or banking access (Losby, Kingslow, and Else 2003).
Trifecta of insecurity	Excessive energy cost burdens for low-income families induce trade-offs between purchasing necessities such as food and medications and paying for utility costs (Knowles et al. 2016; U.S. Energy Information Administration 2017).
Lack of wealth	Redlining and other practices have implications for households of color and their access to capital and housing costs today. Race and gender have been linked to 50% to 75% lower wages and much lower wealth generation over time (Patten 2016). White families have been shown to have eight times more wealth than African American families and five times more than Hispanic families (Bhutta et al. 2020).
Racial and wealth gap	White Americans have a 73% higher average annual income ($68,010 vs $39,299), are two times more likely to be homeowners, acquire 10 times more wealth, and 28 times more likely to be millionaires than non-Hispanic Black Americans (Figure 5). In 2019, while the median racial gap was $164,000, the *mean* wealth gap was $840,000. If a wealth-allocation policy of $7.5 trillion was spread equally across all Black households, then the mean wealth disparity could be reduced by 50%. The mean wealth disparity could be eliminated via a policy of $15 trillion (Welburn et al. 2022).

5.3 Small and Minority Businesses

Small businesses make up 99.9% of all U.S. businesses (32.5 million), create 65.1% of net new jobs, and employ 46.8% of U.S. employees (U.S. Bureau of Labor Statistics 2021; U.S. Small Business Administration 2021). As major contributors to the overall U.S. economy and large consumers of energy, small businesses offer a large potential for energy savings through energy efficiency RDD&D solutions (U.S. Energy Information Administration 2003). A small business is defined by the U.S. Small Business Administration's Office of Advocacy as a privately owned business by the number of employees (less than 250 and up to 1,500) or by the annual revenue (less than $2 million and up to $41.5 million), depending on the industry (Office of Size Standards 2022). This section describes how introducing an energy justice lens could advance technology deployment in disadvantaged communities by focusing on small businesses, small minority-owned businesses, small businesses in disadvantaged communities, and minority-owned businesses.

Small businesses can also be classified as minority-owned based on certain criteria. A certified minority small business must be at least 51% owned and operated by a U.S. citizen that represents at least 25% percent of racial and/or ethnic descent such as Black/African American, Asian American, Pacific Islander, Hispanic, or Native American and other Indigenous (National Minority Supplier Development Council 2022). Minority businesses may have non-minority institutional investors that contributed the majority of a firm's risk capital (equity) and still be certified as a minority business as long as minority owners have at least 25% economic equity, 51% voting equity, and control daily firm operations (Office of Minority & Minority Business Enterprises 2021).

The energy burden and energy insecurity of small business owners and operators are not well understood, as there are very few studies on the conditions of small and minority-owned businesses. There are a variety of business models and conditions that make it challenging to define and understand the impacts. Table 3 presents some of the barriers for small and minority businesses as related to the buildings sector and energy burden.

Buildings in underserved areas are likely to be older and less energy efficient, resulting in higher heating and cooling bills than newer, more efficient buildings. Section 6 describes how these small and minority-owned businesses are likely in the same regions/neighborhoods affected by residential discriminatory policies.

Small businesses and commercial buildings serve important roles in their communities—restaurants, convenience stores, hair salons, etc., all cater to the needs of community residents, employ people who live nearby, serve as meeting points, and help define the character of the neighborhoods. Therefore, a business experiencing energy insecurity and potentially shutting down can have a cascading impact, not only on the people who own and work at that business, but also on the people who rely on that business for employment, goods, and services.

Table 3. Barriers to Decreasing Energy Burden Experienced by Small and Minority-Owned Businesses and Relationship to Energy Justice in Buildings RDD&D

Barriers to Small and Minority Businesses	Energy Justice Considerations in Buildings RDD&D
Racial disparities in access to capital	46% of white-owned businesses accessed credit from banks within the last 5 years, which is double that of businesses owned by African Americans (Raoul 2020). Local capital is often limited. Due in part to the lasting impacts of redlining, 40% or more of the residents in majority-minority neighborhoods live in poverty and lack the resources to invest in local small businesses (Kowalski 2021). Small businesses in majority Black neighborhoods can earn up to 19% lower revenues than similarly sized businesses in majority-white neighborhoods (Toussaint-Comeau, Newberger, and O'Dell 2019).
Favoritism of large commercial businesses over small commercial businesses perpetuates market barriers	Service providers, utilities, and financial institutions often choose to work with large commercial buildings and large portfolio owners because of significant energy savings compared to transaction costs, faster and more attractive returns on investments, and ease of adoption and dissemination of energy efficiency technologies across sizable building portfolios (Langner et al. 2013). These methods of disincentives toward energy efficiency technologies reaching smaller commercial businesses are an opportunity to intervene for equitable, differentiated programmatic design.
Split incentives	Split incentive describes circumstances where investment decisions are impaired based on the transactional contributions of those who contribute and reap the investments and benefits (Itron 2020; Seventhwave, n.d.). Understanding the intersectionality between the type of split incentive issue faced, location, ownership status, density, and demographics of, and service provided to a community is vital. Additional factors on how to equitably address topics like on-bill financing, non-payment default, voluntary models for inclusion of energy efficiency upgrades, and

Barriers to Small and Minority Businesses	Energy Justice Considerations in Buildings RDD&D
	combining with other financing options like utility “system benefit charges” should also be considered (Bird and Hernandez 2012).
High transaction costs relative to energy cost savings	Energy savings that result from energy efficiency solutions in larger buildings can provide expedited return on investment and therefore are more attractive to service providers, utilities, and financial institutions. Therefore, it can be more challenging for a small business to get the financial assistance needed to pursue building upgrades, new technologies, etc. (Langer et al. 2013).
Lack of time to research and implement energy efficiency solutions	Small businesses owners take on multiple roles and typically don’t have an energy, facility, and/or project manager that can set aside time and resources to pursue projects. Therefore, it can be difficult to understand energy efficiency solutions and potential savings. Information is often not readily available for small business owners, hindering business owners from pursuing such projects (Langer et al. 2013).
Lack of available sector-specific resources and technologies	Many energy efficiency technologies are designed for newer, larger, more energy-intensive, owner-occupied buildings (and therefore are not applicable for small businesses) to obtain the greatest possible return on investment, reduction in energy and non-energy inequities such as high energy burden, reported situations of energy insecurity, life cycle, maintenance, and repair costs (Andrews and Krogmann 2009; Langner et al. 2013).

5.4 Rural Households and Businesses

Energy burden and energy insecurity experienced by rural households and businesses are not well understood. Regional research has been limited, and research has only recently been growing on this topic. Nationally, the median rural household energy burden is 42% higher than the median urban energy burden. Rural households, which comprise 16% of U.S. households across 72% of the country’s land area, have a median energy burden of 4.4%, compared to the national median energy burden of 3.3% (USDA 2017). Nationally, rural low-income households experience a higher median energy burden (9%) than non-low-income rural households (3.1%) (Ross, Drehobl, and Stickles 2018). In 2017, approximately 41% of rural households had incomes below 200% of the FPL (U.S. Energy Information Administration 2017). A similar result was found in a Harvard Joint Center for Housing Studies report stating that 41% (5 million households) of rural renters are cost burdened and 21% (2.1 million rural households) spend more than 50% of income on housing (President and Fellows of Harvard College 2017). A 2021 study by SEEA found that southern rural households in extremely low-income to moderate-income households have higher greenhouse gas emissions (635 to 1,752 million lbs CO_{2e}) compared to their urban counterparts (235 to 687 million lbs CO_{2e}) (SEEA 2021). Considering these statistics, and with one-third of rural households experiencing energy insecurity, addressing inequities could be achieved via energy efficiency solutions. Some of the barriers and energy justice considerations for the implementation of energy efficiency programs in rural areas are listed in Table 4.

Table 4. Barriers to Decreasing Energy Burden Experienced by Rural Households and Businesses and Relationship to Energy Justice in Buildings RDD&D

Barrier to Rural Households and Businesses	Energy Justice Considerations in Buildings RDD&D
AMI-based program assistance	Rural areas have higher poverty levels than metro areas, but rural households are often deemed ineligible for federal energy assistance due to their incomes being slightly above program income guidelines for rural areas, which are lower than metro areas (U.S. Department of Agriculture (USDA) 2021).
Limited access to energy efficiency technologies	Rural areas have slower adoption rates of energy efficiency technologies despite higher energy costs, higher energy burdens, and limited access to suitable fuel options. Several market barriers exist in rural areas. Rural areas face a lack of awareness and options for energy efficiency technologies, limited availability of technology options, and a trained workforce to properly install and maintain the systems. The geographic isolation of rural areas leads to a lack of appropriate financing mechanisms (MacDonald et al. 2020).
Favoritism of urban versus rural perpetuates market barriers (e.g., rural energy efficiency gap)	Urban settings lend themselves to easily adopt and disseminate energy efficiency technologies and solutions across sizable building portfolios. Geographic, financial, and awareness and accessibility barriers existing in rural areas impede those areas from receiving the same support for new system upgrades (Winner et al. 2018). Winner et al. (2018) summarized these barriers as: 1. **Geographic**: a. Geographic isolation b. Workforce availability 2. **Financial**: a. High upfront cost of energy efficiency b. Lower median incomes and higher energy burden c. Credit access and debt aversion 3. **Awareness and access barriers**: a. Lack of access to traditional marketing channels b. Lack of awareness or skepticism of existing resources.
Persistence of poverty	Since 2007, the average rural median income was 20% below the average urban median income (Keasling 2019); 85% of the counties in the United States that suffer from persistent poverty are rural counties (U.S. Department of Agriculture 2021). The inability to break out of poverty cycles leads to higher rates of deferred maintenance.
Low property values	Rural area property values are often lower than in metro areas with higher rates of upside-down mortgages (e.g., principal value is higher than the home value), where the owner owes more on the mortgage than the house is worth, which provides a less financial incentive to maintain the property and install new energy efficiency technologies (Fuller 2016). Between 2015 and 2010, the average home value in rural areas increased by 6.25%, compared to 28.4% in urban areas (National Rural Housing Coalition 2019; Keasling 2019). These conditions lead to general deferred maintenance and the rural housing stock becoming more and more dilapidated.
Substandard building conditions due to underinvestment	Years of underinvestment in the renovation of existing and new construction homes in rural areas have led to a housing deficit. Of the total 25 million units in rural and small communities, 1.5 million homes (5%) are considered moderately or severely substandard, 8.75 million homes (30.7%) lack hot and cold piped water, and more than 10 times the national level lack basic plumbing on Native American tribal lands (National Rural Housing Coalition 2019). This housing deficit has reduced the presence of local workers, impeding economic growth and the availability of jobs in rural areas. Average annual production in rural areas fell 30.7% between 2009 and

Barrier to Rural Households and Businesses	Energy Justice Considerations in Buildings RDD&D
	2017 (National Rural Housing Coalition 2019). Secondly, the inadequate quantity of units in rural areas has led to overcrowding. Over 10% of rural units have more than one occupant per room, and 50% of rural housing expenses exceed half of their income.
Lack of workforce (e.g., electricians, plumbers) to install and maintain technologies	Specialists or trained contractor networks are challenging to find and hire, as the local rural workforce is inadequately staffed, trained, and certified to meet the needs of the families and businesses in rural communities. Often, rural efficiency providers undergo tradeoffs between demand of efficiency projects with staff size and training. Implementing adequate access to remote training services that accounts for broadband limitations is vital (Ross, Drehobl, and Stickles 2018).
High shipping costs for equipment	Costs of equipment shipped to rural areas are charged a premium. Equipment requiring premium parts is discouraged and not stocked. For example, the same package could be charged three times higher postal rates for delivery services if shipped to places like Alaska and Hawaii (SJ Consulting Group 2011).

6 Causes and Consequences of Inequities in Disadvantaged Communities

As we push to decarbonize energy systems, we have a pivotal opportunity to revisit how contemporary inequities are rooted in historic inequities—for example, in 2019, the African American homeownership rate was lower than in the 1960s when private race-based discrimination was legal (Chang, Intagliata, and Mehta 2021). Today's social- and energy-related inequities disproportionately suffered by people and communities of color are based on the deeply segregated society developed throughout U.S. history. Traceable from slavery through current discriminatory policies, disadvantage is concentrated through residential segregation in urban areas (Richardson et al. n.d.).

This section describes some of the reasons for (and outcomes of) the inequities in disadvantaged communities, although there are many reasons why people and communities of color live in older housing and/or closer to pollution, traffic, and noise from highways and industries.

6.1 Discriminatory Policies

Throughout U.S. history, discriminatory policies have led to underinvestment in minority neighborhoods and a lack of resources and generational wealth among low-income people and communities of color. Early policies stem from slavery and Jim Crow, and this deep history of segregation and housing injustice has persisted in different ways throughout the 19th and 20th centuries and today. In this section, we discuss specific examples that are most clearly related to the intersectionality between residential and commercial buildings and energy justice, such as redlining, restrictive covenants, the Federal Highway Act, and environmental racism. To understand the magnitude of current social and energy inequities suffered by people and communities of color, we must understand how such discriminatory policies have become intertwined across all dimensions of life.

6.1.1 Redlining

Sanctioned by the Federal Housing Administration and practiced by federal and local government, banking, and real estate industries in the 1930s, redlining was a racial segregation policy in which financial institutions refused to offer mortgages or credit (or offered much worse loan rates) for people to buy houses in neighborhoods occupied by people of color (Mitchell 2018). In 1937, the Home Owners' Loan Corporation formalized guidelines stipulating neighborhood stability based on the presence of "incompatible racial and social groups" (Federal Housing Administration 1938). This became the criteria used during the appraisal and assessment process to qualify for mortgage lending. "Residential security" maps were created by the Home Owners' Loan Corporation's City Survey Program for cities across the country. These maps gave grades to city neighborhoods comprehensively based on sales, location, structural integrity and quality of homes, access to transportation and amenities, and proximity to industrial and commercial nuisances (Federal Housing 1938). Socioeconomic, racial, ethnic, and nationality makeup of neighborhoods were also evaluated. Neighborhoods with a high percentage of minority residents were almost always downgraded to the lowest of the four classification grades (i.e., "hazardous") and shaded in red on the maps ("redlined") (Nelson et al. n.d.).

Redlining resulted in long-term disinvestment in low-income minority communities and is a key factor in the concentration of disadvantages and poverty in communities today (Massey and Denton 1995). This segregation of benefits disproportionately favored white people with lower lending rates, hence generating more equity and wealth than African and Hispanic Americans (Traub et al. 2016). As a result of redlining, African and Hispanic Americans were systematically prevented from building wealth through homeownership. Today in cities throughout the United States, communities of color are concentrated in less-resourced, underinvested neighborhoods that lack economic and educational opportunities for advancement. This discriminatory isolation perpetuates the cycle of African Americans and other people of color living and working in deteriorating infrastructure and poor environmental conditions that negatively impact their health and well-being for generations (Hernandez, Aratani, and Jiang 2014; Lewis, Hernandez, and Geronimus 2020).

The systematic racism of redlining created neighborhoods that today still suffer from higher rates of energy burden, energy insecurity, and exposure to pollution. On average, life expectancy is 3.6 years lower in redlined communities compared to communities that were not redlined (Richardson et al., n.d.). As a result of redlining, 45 million Americans live and work in environmentally health-hazardous neighborhoods and are subjected to worse air quality than those in non-redlined communities. African Americans and Hispanic Americans disproportionately inhale more smog and fine particulate matter ($PM_{2.5}$) from cars, trucks, buses, coal plants, and other industrial sources than white people, due in part to living and working in redlined communities where polluting industries and proximity to highways are prevalent. Even African and Hispanic Americans who live in the same Home Owners' Loan Corporation grade as white people still breathe dirtier air due to their closer proximity to pollution (Lane et al. 2022). This racial inequality and the social patterning of energy insecurity are deeply ingrained in redlined communities.

6.1.2 Racially Restrictive Covenants

To understand the perpetuation of segregation of people of color, typically African Americans, from economic advancement, we must understand the historical context of racially restrictive covenants and their continued existence despite their illegality (Welsh 2018). As a legally enforceable contract, a covenant is a binding promise or obligation to do or not do a particular act (Siles 1968). In terms of residential and commercial buildings, a covenant can be imposed within a deed of real estate property or land (Majumdar 2007).

Racially restrictive covenants were created as contractual agreements and used nationwide to exclude Black families from purchasing homes in white communities through deed restrictions. Starting in 1919, covenants were used by developers to offer "restricted" housing sites that could not be mortgaged, leased, or resold to any person or persons of minority blood or descent despite successful and adequate eligibility (Nelson et al. n.d.). Those who signed a covenant and did not uphold its terms could be sued in a court of law. In other words, racially restrictive covenants made it legal to restrict the sale or resale of property to Black families even if the selling family found a willing and able buyer from a Black family. Racially restrictive covenants were used as a means of residential and community segregation across cities in the United States. Such racial covenants: (1) determined who could buy property; (2) depressed homeownership among African Americans; (3) pushed African Americans and other people of color into redlined areas, which increased the barrier to acquiring affordable financing to buy property; and (4) elevated prices for African Americans to buy property if they tried to buy a home.

The impacts of these racially restrictive covenants broadly influenced beliefs and actions toward minority populations. For example, in 1946, 60% of Minnesotans surveyed believed that African Americans should not have the freedom to live in any neighborhood. Similarly, 68% of Minnesotans asserted that a non-white neighbor would hurt their property values; 64% of those surveyed declared that they would not sell their home to African Americans, even if they offered more than white buyers (Mills, n.d.).

Despite the ban of racially restrictive covenants as part of the Fair Housing Act of 1968, the United States today still deals with the damage imposed by such discriminatory residential and community segregation. The majority of white neighborhoods have higher investments evident through various parks, generous tree cover, community amenities (e.g., grocery stores), and access to resources (e.g., renewable energy) (J. Hsu 2019; Nelson et al. n.d.). Communities of color have more environmental hazards due to the proximity of industrial plants, landfills, and highways; less-resourced schools and other commercial institutions; and less access to medical care (Bulatao, Anderson, and editors 2004) (see Section 6.3.2: Health and Indoor Air Quality).

6.1.3 The Federal Highway Act

The Federal Highway Act of 1956, also known as the Federal Aid Highway Act or the National Interstate and Defense Highways Act, authorized billions of dollars for the construction of an interstate highway system. The interstate highways were often routed directly through communities of color, dividing up neighborhoods and making it more difficult for people to access services (King 2021). The new highways physically separated communities, helping to reinforce the differences in neighborhoods that were already segregated by discriminatory practices discussed above. In addition to separating communities, the highways disproportionally displaced and destroyed the homes, businesses, and houses of worship of communities of color.

In St. Paul, Minnesota, one-seventh of the Black residents were displaced by highway construction (Archer 2021). In addition, communities with highways have higher levels of air pollution and associated health impacts. African Americans and people of color are more likely to live less than a tenth of a mile from major roads and traffic-related pollution (Melton 2017).

6.1.4 Environmental Racism

Environmental racism means unequal access to basic environmental resources or a clean environment. As an example, environmental racism occurs when policies or practices preferentially place industrial facilities in disadvantaged communities. African Americans are 75% more likely than white people to live in areas near commercial facilities that produce odor, traffic, noise, or emissions. More than one million African Americans live within a half mile of a natural gas facility, and 6.7 million African Americans live in 91 U.S. counties with oil refineries (Patnaik et al. 2020). Due to the proximity to these facilities, African American communities suffer from larger exposure rates to environmental hazards (e.g., pollution, lead, foul smells). In 1983, the U.S. General Accounting Office first acknowledged environmental racism and found that 75% of African American communities were living or working near harmful environmental sites such as landfills, plastic plants, power stations, and highways. Several studies have shown that communities living near environmental hazards disproportionally have poor water quality, high exposure to carbon dioxide emissions, lack of sanitation, and high prevalence of health problems such as respiratory illnesses (e.g., asthma) and cancer (Millar 2021).

In the United States, scholars, activists, and journalists have described communities suffering from these inequities, such as lack of access to water due to environmental pollutants, as "Third World areas in a First World country" (United States Congress 1990). Municipalities play a role in local political groups and geography because they determine which areas in the city or town should be incorporated into a municipality via annexation. Such annexation can be used as municipal under-bounding to determine which areas are excluded from municipal services (e.g., deciding that an area with low-income people of color is an unincorporated area) (Marsh, Parnell, and Joyer 2010). This leads to underinvested city resources such as water infrastructure and irrigation systems and/or the ability to reduce the voting power of African Americans (Aiken 1987). Such exclusionary land use planning effectively replaced the more explicit racial zoning laws in the 1960s such as redlining and racially restrictive covenants (Marsh, Parnell, and Joyer 2010).

Over the years, there have been many incidences and examples of environmental racism and its negative ramifications. In 2012, the primary source of drinking water for low-income and minority communities in San Joaquin Valley, California, was exposed to arsenic contamination when pesticides from industrial sources (e.g., wood treatment plants) were collected in the groundwater. Due to the underinvestment in local irrigation and drainage systems in communities of color, higher arsenic contamination was found in these communities, but less contamination was found in areas with higher homeownership rates (Balazs et al. 2012). Similarly, a predominately African American community of 100,000 residents near Detroit, Michigan, was exposed to poor water quality when the city's water source was changed to the Flint River in 2014 to save money. The Flint River source was highly corrosive, causing lead to leach from the old and lead-based water distribution pipes used for local drinking water. Due to historical segregation in Flint, communities of color were primarily subjected to contaminated drinking water and suffered from negative health conditions such as hair loss, skin conditions, lead poisoning, and bacteria derived from Legionnaires' disease (Millar 2021). In 2018, the U.S. Environmental Protection Agency compared the environmental burden of pollution across U.S. communities via an analysis of emission particles. When compared to the overall population, the agency found the burden of pollution was 35% higher for people living in poverty and 28% higher for people of color. African Americans experienced 54% more pollution burden than the overall population (Mikati et al. 2018).

Another example of environmental racism occurred recently in the strip of Louisiana near the Mississippi River originally called "Plantation Country," where previously enslaved or descendants of Black slaves were forced to work in the industrial hub of oil refineries, chemical plants, and plastics plants (*United Nations News* 2021). Now referred to as "Cancer Alley," in 2018 the city council approved legislation to further industrialize this area despite estimates that the industrialization would exacerbate existing environmental pollutants and health concerns for African Americans. Pollutants from industrialization disproportionately nearly double the risk of cancer for local African American communities (104 to 105 cases per million) when compared to the risk of white communities (60 to 75 cases per million). Additionally, the annual CO_{2e} emissions were greater in this new development plant than emissions produced in 113 countries combined (*United Nations News* 2021).

6.2 Persistent Systemic and Structural Discrimination

Sociological literature examines factors associated with the persistence of residential segregation via two categories: systemic and structural racial discrimination. Systemic racial discrimination is the interlocking of racial disparities across multiple dimensions, such as residential location, education, employment and income, access to financial services and credit, justice, healthy food, a clean environment, and quality of health service (Richardson et al., n.d.; Reskin 2012). Structural racial discrimination is discrimination that occurs either intentionally or unintentionally as it relates to institutions in the public and private sectors.

An example of persistent structural racial discrimination is differences in credit histories used to determine the creditworthiness of individual African and Hispanic American applicants (Pincus 1996; Pager and Shepherd 2008). The impacts of discrimination of creditworthiness led to an underinvestment in neighborhoods of color. Such underinvestment results in reduced education and employment opportunities, lower incomes, and less inherited wealth. All these factors negatively impact the capability of attaining a higher credit score. Therefore, access to higher education, higher paying jobs, and home ownership is lower, as the cycle of credit denial perpetuates patterns of economic disadvantage for low-income people of color (see Section 6.3.3: Deferred Maintenance/Cycle of Poverty) (Pincus 1996).

The legacy of racial disparities reinforced by systemic and structural racial discrimination has profound effects on the health of people of color, resulting in a higher prevalence of disease and diminished life expectancy (Williams 1999). It is extremely difficult to eradicate inequities suffered by Black, Hispanic, Asian American, Pacific Islander, Native American, and other Indigenous populations via isolated policy solutions.

6.2.1 Inequitable Business-as-Usual Approaches to Energy Efficiency RDD&D Practices

Historic RDD&D of energy efficiency and renewable energy technologies for residential and commercial buildings is another example of systemic discrimination. Most research and development of new technologies is primarily focused on achieving the highest performance with very little regard for the diversity in deployment or accessibility and affordability of the final product. New technologies usually are designed based on the needs and criteria of higher-income homeowners and commercial building owners who have a higher cost and requirements for specialized training for installation and operations. Typical RDD&D processes do not consider outreach to or the circumstances of disadvantaged communities in product development, nor do they consider the impacts of costs, installation, operations, and maintenance on these communities. The result is that new technologies are installed in buildings where the owners have the financial means and access to technical resources required for new technologies. Deployment activities for new technologies further exacerbate the problems with incentives and outreach programs targeted toward owners with technical resources and higher incomes who are more likely to want the newest and most efficient technologies.

Unfortunately, the result of this business-as-usual approach to RDD&D activities is to further widen the energy performance gap between wealthier communities and low- to moderate-income communities. In addition, low-to-moderate-income communities indirectly contribute to the costs of the R&D (through taxes) and the deployment of incentive programs (through utility costs) without receiving proportional benefits.

Fortunately, the impacts of these practices are beginning to be recognized, and changes are slowly being implemented. Some federal and local incentive programs are more progressive and provide higher incentives based on income level and phase out with higher incomes. Some RDD&D programs are starting to work with community-based organizations to get input from diverse communities and incorporate the findings into the development of new technologies. Many federal funding opportunities now include a diversity, equity, and inclusion component to R&D proposals. There is a learning process, and it will take time for these changes to be fully realized, but there are commitments to change, and there is noticeable progress.

6.3 Consequences of Social and Energy Inequities

As discussed above, communities are often divided by income and race due to the remnants of a highly segregated society (Richardson et al., n.d.). These segregations have led to additional inequities related to building energy and health. This section reviews some of these factors and the resulting consequences.

6.3.1 Urban Heat Islands

Underinvestment and underdevelopment in redlined neighborhoods have resulted in a high incidence of urban heat islands (A. Hsu, Sheriff, and Chakraborty 2021). Heat islands are urban areas with roads, buildings, and other infrastructure that experience higher temperatures than surrounding areas because such structures absorb and re-emit the sun's radiation (U.S. Environmental Protection Agency, n.d.). A recent spatial analysis of 108 communities redlined during the 1930s found that 94% of urban areas have elevated land surface temperatures in redlined areas when compared to their non-redlined neighbors (Hoffman, Shandas, and

Pendleton 2020). Nationally, the land surface temperatures in redlined areas are 4.7°F (2.6°C) warmer than in non-redlined areas, and people of color have a higher exposure to the urban heat island effect in 97% of all major cities in the United States (A. Hsu, Sheriff, and Chakraborty 2021). A separate study described how neighborhoods subjected to discriminatory housing policies within major cities such as New York, Atlanta, Denver, and Portland can be 5°F to 20°F hotter than wealthier parts of the same city (Plumer and Popovich 2020).

To understand the role of extreme heat and urban heat islands, 40 community scientists and university students from Georgia Tech and Spelman College in Atlanta, Georgia, used do-it-yourself temperature sensors to track temperatures by foot or bike (UrbanHeatATL, n.d.). They measured an increase of 5°F in the temperature of concrete surfaces when compared to the outdoor temperature reported by local weather experts (Lucas 2021).

In addition to heat vulnerability, redlined communities are less likely to have residents who can afford to own or run an air conditioner, which can aggravate preexisting health conditions (Huang, Declef-Barreto, and Herrera 2021). For every 2°F rise in temperature, electricity demand increases 1%–9%. Increased peak demand exacerbated by heat islands can lead to system overloads, rolling brownouts, or blackouts (United States Environmental Protection Agency 2021). The historical housing policy of redlining has direct links to the disproportionate heat intensity and associated vulnerabilities experienced by disadvantaged communities in urban environments across the country.

6.3.2 Health and Indoor Air Quality

On average, Americans spend 90% of their time indoors (U.S. Environmental Protection Agency 1989), and indoor environments can contain two to five times higher concentrations of pollutants than typical outdoor environments (Wallace 2002; U.S. Environmental Protection Agency 2021). Those who are most susceptible to the adverse impacts of pollution tend to be those who spend the most time indoors (U.S. Environmental Protection Agency 1997). This includes young children, those prone to asthma, older adults, teachers, school administrators, and people with cardiovascular or respiratory disease (Bridger 2021). There are strong links between energy burden, poor indoor air quality, and negative health outcomes (Singleton et al. 2016).

The older and inferior building stock in redlined communities has serious implications for indoor air quality. Building energy consumption, occupant comfort, and occupant health are closely associated with the building envelope, or the level and condition of insulation, windows, and airtightness. Energy-burdened households or business owners often have homes or buildings with inadequate ventilation, a strong incidence of mold, and regular pest infestation, as well as poor thermal and humidity control (Tonn et al. 2014). More low-income households seek medical care due to insufficient heating or cooling than higher-income households (Xu and Chen 2019). Such problems, which are often due to old, poorly maintained, or inefficient buildings, worsen health conditions such as asthma, malnutrition, and heart disease (Drehobl, Ross, and Ayala 2020). Recent studies have highlighted disproportionate exposure rates to poor indoor air quality based on ethnicity, regardless of income level (Tessium et al. 2021).

Evaluating building characteristics can provide valuable insights into the state of a building's indoor air quality. Buildings can have features that exacerbate indoor air quality problems (Bridger 2021). For example, mold spores and fungi are more able to enter a leaky home

(Barberán et al. 2015), and homes with a high presence of mold have 12% higher median average air infiltration rates (Shrestha et al. 2019). In addition, poor temperature and humidity control can provide prime conditions for mold growth in buildings.

The Colorado Home Energy Efficiency and Respiratory Health (CHEER) study examined 226 low-income households to understand the relationship between energy efficiency retrofits (specifically air sealing of residential building envelopes), air infiltration rates, and qualitative indicators of "healthy homes." The older and smaller homes with correspondingly higher average air infiltration rates had worse indoor air quality, running counter to the notion that tightly sealed homes trap humidity inside. This trend could be explained by leakier homes being subject to more mold spore intrusion from the outdoors (the spores then settle in stagnant locations within the home) and older homes having leaky pipework that provides growth environments for mold. Similarly, this study also found leaky houses near major roads had the highest presence of unacceptable indoor dust levels, mold or stains, vapor condensation on the interior windowpane, poor air freshness (e.g., odors), and inadequate room-to-room temperature variance. The CHEER study found that there was a wide range in the quality of energy efficiency retrofits, which resulted in a lower-than-expected impact on average air infiltration rates. This suggests that quality control should be included and that interventions to improve the air quality of homes should include mold and dampness problems directly rather than relying on these other retrofits to address the problem (Shrestha et al. 2019; Wallace 2002).

6.3.3 Deferred Maintenance/Cycle of Poverty

There is a close connection between energy burden and the cycle of poverty. In the United States, 33% of low-income households are energy inefficient and struggle to afford energy, and 20% of low-income residents must decide between paying for energy usage and other necessities such as food or medicine (Urban Energy Justice Lab 2017; Hernandez 2016). Likewise, low-income households with high energy burdens are more likely to report issues such as food insecurity and housing instability (Hernandez and Bird 2012). The most common reason consumers take out small payday loans, which often have extremely high interest rates, is to pay utility bills (Levy and Sledge 2012). The additional cost burden of the interest on these loans results in 40% of borrowers failing to pay the loan when it first comes due, and payday loan borrowers taking an average of 11 extensions per year. This leaves such borrowers in debt for approximately half the calendar year, exacerbating the cycle of poverty for the sake of continued energy services (Levy and Sledge 2012).

Rural communities experience a significantly higher average energy burden than the national average, and rural low-income households even more so (Ross, Drehobl, and Stickles 2018). Often these rural households do not have the capital to invest in energy efficiency upgrades or other measures that would help reduce their energy burden, continuing the cycle of poverty.

Finally, the stress from large or overdue energy bills can contribute to mental health issues such as depression or anxiety (Hernandez and Bird 2012). Mental health issues can also contribute to financial hardships, creating a reciprocal relationship (*Mental Health Foundation* 2021). Improving buildings and building technologies to reduce energy burdens for households can therefore also help improve community health (U.S. DOE Better Buildings, n.d.).

7 Conclusions and Opportunities for a Just Energy Transition

The research, development, demonstration, and deployment of building energy efficiency technologies and solutions has made significant advancements in performance across a broad range of technologies in recent years. These advancements have been conducted with a technical performance target approach, resulting in high performance that is not always broadly deployable or needs additional upgrades to function in the future. To equitably decarbonize our buildings and energy systems by 2050, we need technologies that work for all building types, all occupants, and all communities. Buildings and business owners in disadvantaged communities often have fewer benefits from new technologies and in some cases see energy costs increase from deployment of new technologies in other communities. This process has perpetuated economic, energy, and health inequities that have persisted for generations in the United States. The Biden-Harris administration recognized these inequities and created the Justice40 Initiative to deliver at least 40% of the overall benefits from federal investments in climate and clean energy to disadvantaged communities.

This report presents a background on building energy and environmental justice inequities and provides an important starting point to consider how energy and environmental justice can be centered in efficiency efforts for residential and commercial buildings in disadvantaged communities. Energy and environmental justice represent a critical opportunity for buildings researchers and decision makers to understand how historical legacies of energy and non-energy inequities have a role in the RDD&D of buildings. Sponsors of buildings RDD&D have the following opportunities to integrate energy and environmental justice:

- **Require projects and program design efforts at the onset to:**
  - Include meaningful direct involvement with disadvantaged populations, businesses, tenants, and local communities via paid advisory group roles.
  - Incorporate actionable and measurable metrics of success with disadvantaged communities using energy and environmental justice metrics and methods.
- **Ensure annual program evaluation reviews include** diversity, equity, inclusion, accessibility, and energy and environmental justice metrics.
- **Develop representative data sets, analysis tools, and new technologies** that better quantify how assumptions made in the RDD&D process impact communities. Specifically, representation and related assumptions that happen early in RDD&D processes impact which opportunities disadvantaged communities will have to adopt efficient technologies, and which burdens they will still be disproportionately impacted by.
- **Dedicate new projects to focus on solutions for disadvantaged communities** and ensure that there is adequate near-term and long-term funding to support representatives from these communities to participate in the planning and implementation of these projects.
- **Develop field validation guidance** for working in disadvantaged communities to ensure that these projects are planned and evaluated appropriately.
- **Require that new technology field validation efforts include projects in disadvantaged communities** and integrate the tenets of energy justice.

- **Establish working partnerships** with regional energy efficiency organizations, key community-based organizations, and experts from (and those who live in) disadvantaged communities to share information on challenges and opportunities in different communities and to plan for future deployment efforts.
- **Establish an external advisory board** for energy justice directly with disadvantaged communities to guide research directions, deployment opportunities, and accountability of activities.

As this report has shown, the United States is experiencing the consequences of a segregated society and profoundly unequal building, energy, public policy, and housing systems. These strategy options represent actionable first steps to achieve an equitable, clean, and just energy transition, as future action will require serious, dedicated efforts.

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