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Income, housing and health: Poverty in the United States through the prism of residential energy efficiency programs

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ABSTRACT

This paper explores the intersection of poverty, housing, and health among low-income weatherization program participants in the United States. These income-qualifying programs seek to reduce energy burden, which is the proportion of a household's annual income spent on residential energy. These programs produce secondary benefits by reducing material deprivation, health inequalities, and energy poverty (which differs from energy burden in that it considers whether households are compressing their energy needs to meet what they can afford). This paper mines survey data from four evaluations of weatherization programs to provide new insights into the characteristics of households and their homes entering weatherization programs. These data allow assessments of similarities and differences by housing type (single-family, mobile home, and multifamily) and region that could then provide insights into health and social determinants of health non-energy impacts accruable by different weatherization programs. These data also provide an opportunity to assess more specific aspects of poverty and health. The results provide several important insights. One, contrary to expectations, households residing in mobile homes do not appear to be facing more hardship than those who live in single-family homes. Also contrary to expectations, households living in multifamily buildings appear to be facing less financial hardship and live in better housing conditions than their counterparts who live in single-family and mobile homes. Two, it was found that there are significant differences between household status within each program. Approximately 20–30% of households report significant material deprivation and poor health whereas 50–75% of households do not. Demographic analysis found that the former can be described as "near-elderly" with less employment prospects and less access to health care. A majority of the latter report being retired and therefore more likely to receive social security benefits and Medicare. Weatherization programs could move beyond limiting eligibility criteria to income poverty to better target their programs to households that suffer higher levels of financial hardship, material deprivation and health problems. The programs could also consider collaborating with the health care and public health sector to identify and refer households in most need of their services.

1. Introduction

This paper assesses poverty through the prism of several low-income residential energy efficiency programs administered in the United States (U.S.). Referred to herein as weatherization programs, these programs all offer comprehensive home energy retrofits that commonly install air sealing, insulation, and heating repair and replacement measures. Along with the mission of reducing energy use for low-income-eligible households the major motivation of these programs is to reduce the suffering of energy burden.

Research shows that weatherization programs also yield a wide range of secondary positive consequences, or non-energy impacts (NEIs). For example, emissions of greenhouse gases and other air pollutants can be reduced by reducing energy consumption. Expenditures by weatherization programs can also create employment opportunities in the communities where weatherization is conducted. Research also shows that weatherization can improve the health and safety of occupants and help reduce financial stress.

To help evaluate household related NEIs, households are surveyed pre- and post-weatherization. The surveys typically include questions about home conditions, health, and budget situations that are hypothesized to be impacted by weatherization. Examples of home conditions

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include: how frequently homes are kept at unsafe temperatures and whether homes are infested by pests. Many health questions are related to asthma and other respiratory conditions, thermal stress, and arthritis. Budget questions address how hard it is for households to afford their energy bills and how often they may not buy food or prescriptions in order to pay utility bills. These surveys are unique in that they contain questions about energy poverty, housing, health, household finances and quality of life that are not normally combined in social science surveys [1].

This paper presents data mined from completed surveys from four evaluations of weatherization programs and provides new insights into the characteristics of households and their homes entering weatherization programs. These data also allow assessments of similarities and differences by housing type (single-family, mobile home, and multi-family) and region (e.g., national versus Southeastern U.S.) that could then provide insights into health and household NEIs attributable to different weatherization programs. These results could be valuable to federal, state, utility, and local weatherization programs.

These data also provide a unique perspective of poverty in the U.S., following Veelen et al. who state that "what a focus on energy makes visible and thinkable that other entry points do not [2]." The survey questions explore not only energy burden issues but also aspects of poverty that fall under the rubric of material deprivation and hardship. Does material deprivation differ amongst weatherization recipients across housing types? Across regions? Possibly even more importantly, do weatherization households differ significantly across multiple dimensions of poverty within programs and if so, do these insights have implications beyond the energy efficiency community? The results presented below indicate that the answer to these questions is yes.

Section 2 lays the foundation for this paper by addressing three topics: energy poverty, multiple dimensions of poverty, and poverty and the near-elderly in the U.S. As noted above, most weatherization programs aim to reduce energy burdens, but energy poverty is a much larger concept and includes other dimensions; such as adequate access to energy (Section 2.1). Poverty in general is typically defined by household income. Certainly, this is the standard used by weatherization programs to determine program eligibility. Unfortunately, while weatherization can reduce energy burdens, it cannot directly lift households out of poverty as defined by one's socioeconomic status. On the other hand, weatherization can positively impact other dimensions of poverty, which are set out in Section 2.2.

Section 2.3 addresses the poverty of the near-elderly – defined as individuals in the 55–64 age range. Our data suggest that near-elderly households suffer from higher energy burdens, worse health, and higher material deprivation than other weatherization recipients. Insights on the poverty of this specific demographic has only been lightly regarded in the literature but could have broad implications for social policy in the U.S.

Section 3 focuses on weatherization and its potential impacts on multiple dimensions of poverty. Section 3.1 presents a theory of change model that underlies hypotheses about how weatherization can simultaneously impact energy poverty and multidimensional poverty. Section 3.2 summarizes research that supports these hypotheses. Section 4 describes data used for the analyses. Section 4.1 presents the four evaluations that yielded survey results used herein. Section 4.2 describes the instrument used to survey weatherization recipients as part of each evaluation.

The results are presented in Section 5. The first three sections present demographic, and baseline health and material deprivation (i.e., home conditions and financial constraints) statistics across the four evaluated programs. These tables are designed to provide insights across programs, housing types and regions. Section 5.4 presents the results of cluster analyses used to assess within program differences in health and material deprivation. These results show a wide disparity between the 'best' off households and the 'worse' off households with respect to material deprivation. Results presented in Section 5.5 suggest that the worse off households are headed by near-elderly and the best-off households are generally headed by retired individuals. Section 5.6 explores whether differences in health and material deprivation can be explained by differences in social determinants of health (SDOH). Section 5.7 clusters households by health issues and then explores congruities and incongruities between baseline budget and health conditions. Section 6 discusses how these results are relevant to the energy efficiency and broader social welfare communities.

2. Literature review

2.1. Energy poverty

Access to affordable and reliable energy can be seen as a basic human right [3]. Violating this human right is fundamentally a socio-political injustice [4]. Similar to general poverty, energy poverty is normally associated with household income. Different from general poverty, energy poverty is measured by energy burden – which is a function of energy consumption divided by household income, expressed as a percentage. In the U.S., low-income households typically have an energy burden three times greater than non-low-income households [5]. An energy burden exceeding 10% is generally considered an indication of energy poverty [6]. A recent study added two additional categories, "energy stressed" (4–7%) and "energy burdened" (7–10%), to capture the range of financial hardship relating to energy [7,8]. Others put forward a 6% cut off for energy poverty based on the notion that housing costs should not exceed 30% of income, with no more than 20% of housing costs allocated for energy [8,9]; according to this logic, energy poverty would not be influenced by cost of living factors other than housing prices.

Notably, the U.K. government previously defined energy poverty as having an energy burden exceeding 10% [1] but revised its definition following a 2012 report investigating the causes and characteristics of domestic fuel poverty [10]. The report concluded that energy burden had both merits and flaws, including in the latter its sensitivity to energy prices and issues with accurately calculating income; the author asserts, "The trends it reports do not well reflect changes in the underlying problems, and its definition can encompass households that clearly are not poor." The new definition does not mention energy burden and instead specifies two metrics: 1) a household's "required fuel costs" must be above the national median, and 2) if the household spent this amount on fuel, their remaining income would put them below the poverty line [11]. Others in the U.K. and Europe more broadly have continued to refine methods of measuring energy poverty and its effects without relying solely on energy burden [12–16].

As indicated in part by this shift in policy, the simple definition of energy poverty as energy burden obscures many other important aspects of energy poverty [17]. A singular energy burden estimate may obscure whether households are compressing their energy needs to meet what they can afford, are able to satisfy their energy needs, or maybe even wasting energy, though few low-income households fall into the latter category [18]. This singular metric also hides how serious the consequences of energy poverty could be if households are not able to heat their homes above unsafe temperatures [19]. For example, a study in Spain found that 11% of homes could not heat their homes to adequate temperatures [20]. Also hidden are the fear and stigma members of energy vulnerable households may feel [21] and the relationships between energy use and a minimum standard of living [22].

Energy poverty is a serious issue in the United States [23,24] and internationally [25–29]. The U.S. Department of Energy estimates that over 30 million households in the U.S. are substantially burdened by energy costs [30]. The number of EU households estimated to suffer energy poverty is 50 million [31].

Boardman [32] and others [33] argue that energy poverty should be viewed as distinct from general poverty because energy poverty can be solved through capital investments in homes and in the energy

infrastructure. Indeed, weatherization programs do invest in the installation of energy efficiency and conservation measures that increase the performance of homes, with the average lifetime of such measures approaching 20 or more years. Additionally, these programs can be straightforwardly given to utility companies and governmental energy efficiency programs to implement. On the other hand, this view has siloed energy poverty programs from other efforts to reduce poverty. It can also be argued that this view has artificially constrained societal investments in improving low-income housing that could reduce energy burdens while also improving health and reducing material deprivation. Making this case to the health care and public health sectors in the U.S. is a major motivation driving recent NEI research [34,35].

2.2. Multiple dimensions of poverty

Similar to energy poverty, general poverty is conventionally defined in terms of income. Income thresholds are set such that households falling below the thresholds are deemed to lack enough income to support an acceptable quality of life. Such thresholds are used by most poverty programs in the U.S. to determine eligibility for social programs, including weatherization programs. While thresholds are administratively manageable to implement, their development and use is not without complexity and controversy. For example, should the thresholds be set to express absolute or relative poverty, and should thresholds reflect other underlying features of poverty [36]? Additionally, strict income-threshold definitions of poverty also hide the non-income components of poverty [37].

Amartya Sen defines poverty as the deprivation of a person's capabilities to live the life they have reason to value [38]. This powerful definition expresses the various aspects of poverty experienced by the poor in the Global South, encompassing lack of clean water and sanitation, threats from a wide-ranging set of deadly diseases, and lack of basic freedoms. Poverty in the Global North may not share all of the same features, but it is multidimensional nevertheless [39].

A multidimensional understanding of poverty needs to move beyond monetary indicators to encompass non-monetary indicators [40]. For example, Glassman presents a seven-scale multidimensional poverty index that has these components: health, education, standard of living, consumption, economic security, housing quality, and neighborhood quality [41]. Schenck-Fontaine and Panico propose these three dimensions of economic hardship: income poverty, material deprivation and subjective financial stress [42].

Drawing from our survey questions, our case studies, and our listening sessions with weatherization recipients across the U.S., the concepts of hardship and material deprivation come closest to capturing what we see in the data and have experienced in the real world. Townsend used the term deprivation to describe the broader notion of 'inability of living a decent life' [43]. Material deprivation or hardships have been variously defined as having these components:

- bill-paying hardship, food hardship, health care hardship [44];
- food insecurity, inadequate housing, unmet medical needs, utility cutoffs, and financial insecurity [45];
- not having access to a car, not being able to pay utility bills, and not being able to pay rent in the past year [46]; and
- income deprivation; employment deprivation; health deprivation and disability; education, skills and training deprivation; barriers to housing and services; crime; and living environment deprivation domain [47].

Each of these frameworks has something to offer with respect to understanding the potential impacts of weatherization on material deprivation. The multidimensional approach to poverty that comes closest to our theory of change with respect to weatherization presented in Section 3.1 was developed in New York City to study Wellbeing and is called the "Poverty Tracker" [45]. This model has these three major components:

- Income Poverty;
- Material Hardship (including indicators of food insecurity, housing hardship, unmet medical needs, utility cutoffs, and financial insecurity); and
- Adult Health Problems (which can drain family time and resources).

2.3. Poverty and the near-elderly

In the U.S., there are growing concerns about the fraying of the social safety net and about people in poverty falling through the administrative cracks of the U.S. social programs. A recent review found that over 25% of Americans deemed to be suffering income poverty receive no help from food stamps, subsidized housing, welfare or other case benefits [48]. As presented in Table 1 below, the main respondents to our surveys of weatherization recipient households are in their late 50s, which suggests that we should pay particular attention to the health and hardships faced by the elderly. Indeed, we find that there are growing concerns about the lack of financial security of elderly households [49–51]. U.S. poverty rates for 2019 stratified by ten-year age brackets show a downward trend from ages 18–54, but then a slight spike for those age 55–64 before declining again in the group aged 65–74 [52].

This concern extends to the up-keep of homes. There are many reasons why homeowners do not, or are unable to, invest in their homes [53]. It is worrisome that elderly homeowners that live in old, inefficient dwellings can easily fall into fuel poverty because they lack the financial capability to maintain their properties [54]. Table 3 below supports these observations by indicating that the baseline conditions of single-family (SF) and mobile homes (MH) (the majority of which are owner occupied) of weatherization recipients are worse than conditions found in renter occupied multifamily (MF) buildings (i.e., buildings with 5 or more units).

Results presented in Section 5.5 do indicate that the demographic most likely to live in poorer housing conditions and experience other aspects of material deprivation is the near-elderly. These individuals are

Table 1
Survey questions and NEI indicators.

Topics and indicators
Health
▪ Asthma Rates – Told have asthma by doctor and still have asthma
▪ Asthma – ED visit in past year (yes)
▪ Home kept at unhealthy temperature some or all of the time (yes)
▪ More severe headaches in past year (yes)
▪ Someone in household had the flu during the past year (yes)
▪ Someone in household had a sinus infection past year (yes)
▪ Respondent number of days previous month physical health not good
▪ Respondent number of days previous month mental health not good
▪ Respondent bad days rest/sleep last month
Home conditions
▪ How often home too drafty past year? (all to some of the time)
▪ How much outdoor noise intrudes into home? (a great deal to some)
▪ How infested is home with cockroaches, other insects, and spiders? (extremely to somewhat)
▪ How infested is home with mice? (extremely to somewhat)
▪ Home has frequent mildew odor or musty smell? (yes)
▪ How often have observed standing water in home? (always to sometimes)
▪ Have seen mold in home past year? (yes)
Budget issues
▪ It is hard or very hard to pay energy bills (yes)
▪ Received a disconnect notice past year (yes)
▪ Did not buy food to pay energy bills past year (yes)
▪ Did not pay energy bills to buy food past year (yes)
▪ Received food assistance (e.g., WIC) past year (yes)
▪ Did not pay energy bill to fill prescriptions past year (yes)
▪ Did not fill prescriptions to pay energy bills past year (yes)
▪ Could not afford prescriptions past year (yes)
▪ Used one or more short-term, high-interest loans to pay utility bills past year (yes)

in the 55–64 age range and are too young to retire and qualify for Social Security.

Challenges faced by the near-elderly started to appear in literature around the year 2000. Specifically, the papers focused on the lack of affordable health insurance held by this cohort [55], which then led to higher rates of diseases such as diabetes, hypertension, and heart disease [56]. Proposals were made to extend Medicare coverage to the near-elderly to reduce health inequities [57–59] and have recently resurfaced [60]. These proposals were not adopted in the U.S. and the plight of the near-elderly seems to have disappeared from the ensuing literature. One of the contributions of this piece is to re-animate concerns for this cohort of the U.S. population.

3. Weatherization

3.1. Overview of weatherization in the U.S.

The prototypical weatherization program in the U.S., and also its largest, is the Weatherization Assistance Program (WAP) administered by the U.S. Department of Energy (DOE). This program provides grants to states, which then provide grants to local weatherization agencies to conduct weatherization services. Homes going through the program receive energy audits first, and then based on the audit results, energy-saving measures tailored to the home are installed. Common measures include air sealing, insulation, furnace repair and replacement, and duct sealing, though WAP and other programs also allow funds to be spent on health and safety measures. All homes are inspected post-weatherization. WAP funds the weatherization of SF and MH as well as MF buildings; in total, the program was the sole or primary funder for weatherizing over 37,000 homes in 2018, though over 30 million homes in the U.S. are eligible for weatherization services annually [61,62]. To demonstrate the WAP's potential to weatherize more homes, increased funding from the American Recovery and Reinvestment Act (ARRA) supported the weatherization of over 330,000 homes per year in 2011.

Many utilities offer low-income programs as part of their regulatory social contract [63]. Other funding comes from states, systems benefit charge programs, and re-programmed federal funds from the Low-Income Home Energy Assistance Program (LIHEAP). Combined, these sources provide leveraged funding of $3.48 to every dollar invested by DOE WAP – in addition to spending on programs not administered by WAP (e.g. in-house, utility-run energy efficiency programs) [61] – and fund the weatherization of approximately one million units per year, far below demand. Wait lists are long and detrimental [64].

3.2. Theory of change

It is hypothesized that important co-benefits of low-income weatherization are reductions in energy burden and material hardships and improvements of the health of occupants. Fig. 1 is illustrative of the relationships between weatherization and these components of poverty. To begin, weatherization directly improves the physical condition of the home resulting in two major impacts: impacts upon resident health and safety; and impacts on energy cost savings that reduce energy burdens, as well as material hardships in other areas. Improvements in household members' health and financial situations result in positive feedback responses to each other.

In many cases, comprehensive weatherization of homes is required to produce the most impactful health benefits. For example, air sealing, insulation, and cleaning of furnace and dryer filters are among many weatherization measures that can reduce the frequency of asthma flare-ups. It can also be argued that comprehensive weatherization of homes is also needed to reduce heat and cold stress, flus and colds, and headaches. It should be noted that most of the aforementioned health benefits accrue from the installation of standard weatherization measures to save energy, and not from the additional installation of health and safety measures.

On the other hand, some measures can unilaterally impact health. For example, installation of carbon monoxide (CO) monitors can reduce CO poisoning. Replacing an energy inefficient refrigerator that also is unable to keep food safely cool can reduce household costs from food spoilage and potentially reduce food poisoning. Lowering the temperature on water heaters to save energy can also potentially reduce scalding.

3.2.1. Weatherization's impacts on energy poverty

Evaluations of weatherization programs find that energy consumption and energy cost burdens of low-income households are significantly reduced by the programs [70]. For example, a comprehensive and rigorous evaluation of the energy savings attributable to WAP found that weatherization reduced natural gas consumption in SF homes that heat with natural gas by 17.8% and the annual energy cost savings for these homes was $239 [71]. Using the present value of the energy costs savings taken over 19 years, the ratio of energy cost savings to the costs of the installed measures was 1.72. These results are reflective of the results of other evaluations of the energy savings and energy cost savings attributable to weatherization programs in the U.S. It should be noted that energy cost savings provided by weatherization may not always alleviate energy poverty [72,73].

3.2.2. Weatherization's impacts on health

Weatherization can also be seen as a nexus point between housing, health, and energy consumption. Poor indoor air quality and extreme outdoor air temperature can cause or exacerbate health problems for economically disadvantaged individuals and families living in sub-standard housing in America [74–76] and elsewhere in the world [46,54,77–81]. From an energy efficiency perspective, many vulnerable people are essentially living in tents [77]. It is not surprising that this has adverse health effects.

Research shows that weatherization has significant health benefits [25,65,66,69,82–85] and improves overall quality of life [86]. For example, improvements in dwelling quality (e.g. air sealing measures) reduce exposure to evidence-based asthma triggers (e.g., pests and outdoor allergens) thereby reducing asthma flare-ups.[1] Weatherization directly reduces risks of thermal stress on occupants (e.g., air sealing and insulation decrease drafts and unsafe temperatures inside the home, and improve the resilience of homes during power outages and extreme weather events), and also reduce health risks associated with home fires and CO poisoning (i.e., through the installation of CO monitors and ensuring that combustion appliances vent properly) [87–90].

Current research in the MF sector suggests that the benefits may also extend to decreasing symptoms of certain types of arthritis [91].

Weatherization also improves indoor environmental quality [92–95]. For example, reduced intrusion of outdoor noise from air sealing and insulation can improve mental health and quality of sleep [65,96]. In summary, there are complex and indirect relationships linking energy efficiency measures to outcomes on all dimensions of health which contribute to significant material and psychosocial benefits [97].

3.2.3. Weatherization's impacts on material deprivation

NEI research finds that a household's financial well-being can improve post-weatherization through reduced energy and water costs, and reduced frequency of utility disconnect and reconnect fees, for example. Improved health of those employed and of children can also result in reduced missed days of work and school, directly and positively impacting household budgets.

[1] It should be noted that asthma rates are higher than the national averages amongst low-income individuals [66]. Additionally, thermal stress is another example of a national health inequity [67] and is expected to worsen over time due to climate change [68].

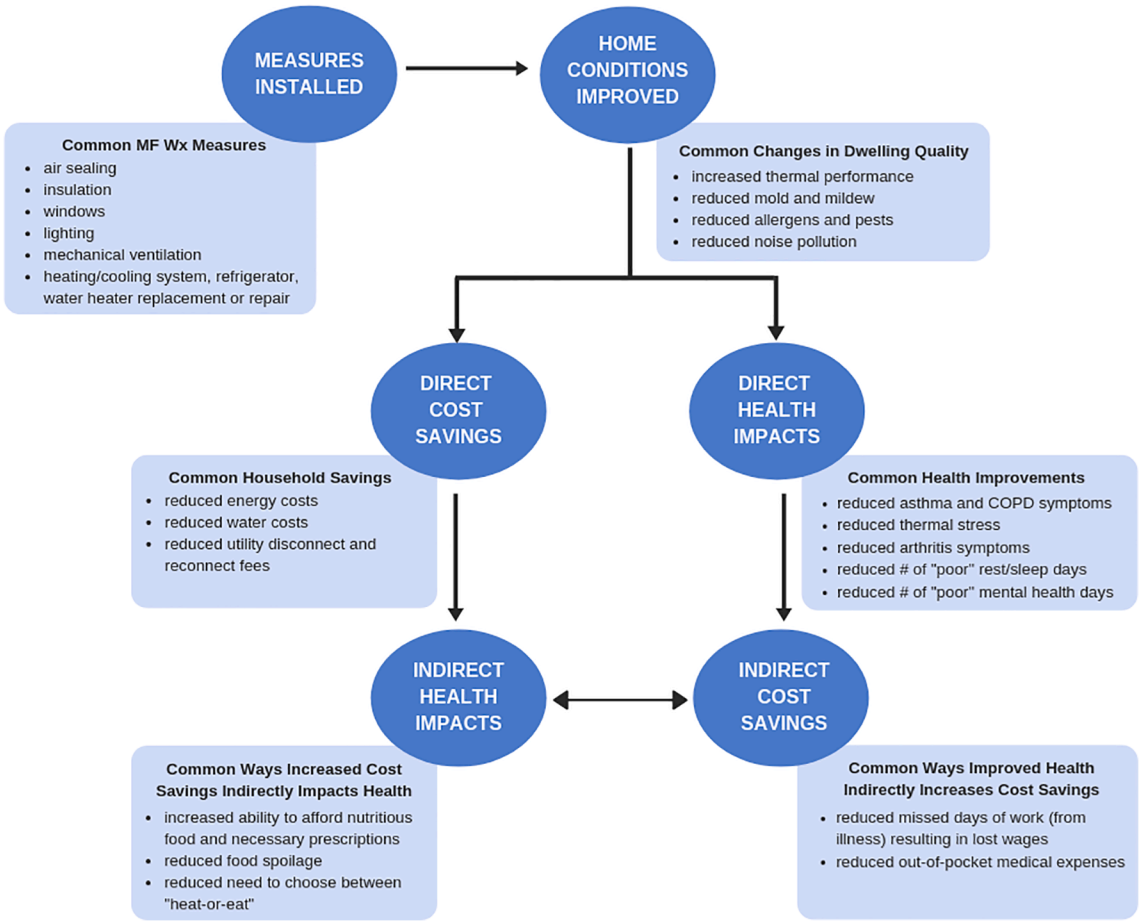

Fig. 1. Weatherization's impact upon poverty: theory of change.

Households are less likely to trade-off buying food to pay utility bills, thereby reducing food insecurity [98]. Households are also more able to afford prescriptions. Improved health of all household members leads to reduced missed days of work for primary wage earners. This translates to a direct increase in income for many because three-fourths of low-income workers do not have paid sick days [99]. Occasionally households also take out fewer short-term predatory loans after weatherization [96]. The monetary value of the benefits to households and society may exceed the energy cost savings benefits and program costs [96].

The nature and extent of NEIs are dependent not only upon the type and number of weatherization measures installed but also upon the characteristics of the recipients and their homes. For example, the thermal comfort benefits of weatherization, which then might reduce thermal-stress related health-care system encounters, might be higher for programs that serve an older demographic or children [78]. Conversely, weatherization might benefit asthma suffers more who live in SF homes that receive air sealing measures than large MF buildings that often do not.

3.2.4. Other NEIs

Assessments of the NEIs of weatherization programs are also regularly conducted [100,101]. Well known NEIs of low-income weatherization programs include: reductions in greenhouse gas emissions and emissions of other pollutants; local employment; water savings; and utility benefits such as reduced arrearages and avoided generation costs [102–104]. Promoting energy efficiency also goes hand-in-hand with helping utilities meet their renewable energy goals cost effectively by reducing overall and peak loads, which can be challenging to meet at their current levels with renewable energy technologies [105].

4. Overview of data sets

4.1. Weatherization programs

Four different data sets are used in this study. Here are brief descriptions.

4.1.1. U.S. Department of Energy's (DOE) weatherization assistance program (WAP)

WAP is a U.S. federal program administered by the U.S. Department of Energy. As noted above, WAP provides grants to states and territories, who then provide grants to local weatherization agencies to deliver free weatherization services to income-eligible households. WAP operates in all areas of the country. WAP weatherizes SF, MH, and MF buildings.

WAP was recently evaluated [68,103,106]. As part of these evaluations, a national survey of WAP recipients was conducted. The phone survey was administered in 2011/2012 to a randomly selected set of treatment (about to be weatherized) and comparison (weatherized one-year previously) households living in SF and MH, drawn from a random sample of local weatherization agencies from around the country. 90% of the homes are owner occupied. Only the 665 treatment homes that answered the first, pre-weatherization survey are used in the analyses below. The survey contained questions about home conditions, health, household budgets, and demographics.

4.1.2. Knoxville extreme energy Makeover project (KEEM)

The Knoxville Extreme Energy Makeover Project (KEEM) weatherized owner occupied, SF, electricity heated homes in Knoxville, Tennessee from 2016 to 2018. Funding for KEEM was provided by the Tennessee Valley Authority (TVA). The homes were weatherized by the

local community action agency, City of Knoxville-Knox County Community Action Committee (CAC). During the early stages of the project, homes were heavily recruited from historically under-represented minority communities in Knoxville.

The Robert Wood Johnson Foundation provided a grant to assess the health and SDOH benefits of KEEM. A phone survey was administered to all homes that KEEM weatherized between 2016 and 2017. Contact information was provided by CAC. Surveys were administered after homes received energy audits but before homes were weatherized and then again one year later. The Center for Applied Research and Evaluation (CARE), University of Tennessee, Knoxville, administered the phone survey. The control group sample was drawn from CAC's Knoxville waiting list for their KEEM, WAP, and local-utility funded programs. A random sample of KEEM homes weatherized one year previously was also surveyed to create a comparison group. Households were provided a $20 incentive for each completed survey. For the research reported below, the pre-weatherization treatment and control group samples were combined and yielded an n = 251.

4.1.3. Low-Income multifamily buildings (LIMF)

The JPB Foundation and the Energy Efficiency Program Administrators in the Commonwealth of Massachusetts provided funds to estimate the health and resilience benefits attributable to weatherizing low-income MF buildings (LIMF) located in the Northeast and Midwestern regions of the United States. MF buildings in our sample had 5 or more units. We worked with state and local weatherization programs, utilities that offer MF weatherization, non-profit low-income and affordable housing advocates, and non-profit and commercial owners of affordable MF buildings to construct a convenience sample of treatment, control, and comparison buildings.

Treatment, control, and comparison group households were first surveyed between 2018 and 2019. Based on recommendations provided by property managers and owners, paper surveys were translated into Spanish, Mandarin and Russian. The project team asked property managers and property owners for permission to enter buildings to hang survey packets on residents' doorknobs and in the appropriate language if known. Each clear bag contained a cover letter, a paper survey, and a pre-paid return envelope. Survey packets were hung on every door in a visited building, except for the largest MF buildings, were surveys were hung on every other or every third door, though in some buildings project staff personally handed the surveys to primary respondents and were able to wait in the building until the surveys were completed. Over 7700 surveys were distributed. Potential participants were also given the option of completing the survey over the phone or via the web, though most chose to fill out the paper survey.

Respondents mailed completed paper surveys to CARE for processing; CARE also administered the phone and web versions. Households were provided a $25 to complete each Phase 1 survey – $45 for Phase 2 to increase response rate. Data provided by the LIMF sample presented in this paper is from the treatment and control groups pre-weatherization (N = 1,268) that were surveyed 2018/2019.

4.1.4. Home Uplift (HU) initiative

The Home Uplift (HU) Initiative is a low-income weatherization program funded by TVA and local power companies in its jurisdiction. It is the successor to TVA's Extreme Energy Makeover initiative. The five major cities in TVA's region are participating in HU: Knoxville, Nashville, Chattanooga, and Memphis, Tennessee, and Huntsville, Alabama. There are also a small number of rural communities in Mississippi and Kentucky represented in our sample of homes. HU's eligibility requirements and weatherization procedures are directly taken from WAP. HU weatherizes SF homes and a small number of MH. Most are owner-occupied. The small number of homes from Huntsville are owned by its public housing program.

TVA provided funds to estimate the health and SDOH benefits attributable to HU. Similar to KEEM, CARE administered the phone surveys just after homes received their energy audits but prior to weatherization and again one year later. All HU homes that received energy audits between 2018 and 2019 were contacted by CARE. The control sample was drawn from waiting lists, mailing lists, and lists of income-eligible homes that received housing and energy assistance. Households were provided a $30 incentive to complete each survey. The survey data reported below were collected pre-weatherization in 2019/2020 from 997 treatment and control homes.

4.2. Household survey questions and NEI Indicators

Table 1 lists the health and material deprivation-related (i.e., home conditions, household budget issues) questions that were included in the household surveys conducted as part of each of the four evaluations described above. The majority of these questions were drawn from other existing surveys, such as the Behavioral Risk Factor Surveillance System (BRFSS) and the Residential Energy Consumption Survey (RECS). The surveys were pre-tested prior to implementation as part of each evaluation. These questions were complemented by demographic questions, which are presented in Table 2.

5. Results

5.1. Demographics across regions and building types

Table 2 presents baseline demographic descriptors for households in the low-income weatherization space. Overall, the main respondents are female and in their upper 50′s. The results also illustrate the demographic differences by home type and location. As could be expected, household sizes in the MF sector are much smaller than in the SF sector, almost one person less than found nationally. The small size of the Knoxville households was unexpected. The small households in the MF sector are also reflected in the much lower percentage of married respondents. A second notable demographic difference is race. Black households are more represented in the KEEM, LIMF and HU samples than WAP because the former three are quite focused on urban populations. WAP serves both urban and rural areas, and the WAP evaluation survey sample does not include MF buildings. The last notable demographic difference is related to work status. Though the average respondent ages are relatively similar across the four samples, a much higher percentage of LIMF respondents report being retired and/or not employed; this may be in part because 28% of the sample was supportive housing and 33% senior housing.

5.2. Baseline health conditions across regions and housing types

The next table (Table 3) provides several descriptive statistics on the

Table 2
Demographics – all sample groups combined.

Demographic characteristic	WAP (n = 665)	KEEM (n = 251)	LIMF (n = 1297)	HU (n = 997)
Respondent Gender: Female (%)	73%	78%	64%	82%
Respondent Age	57	55	58	61
Average Household Size	2.38	2.11	1.53	1.97
Black or African American (%)	18%	28%	42%	77%
Respondent Employed (%)	34%	35%	25%	25%
Respondent Retired (%)	31%	24%	43%	42%
Respondent Married (%)	32%	26%	10%	15%
Respondent Education: GED or less (%)	60%	52%	58%	52%

Table 3
Baseline health issues.

Health indicators	WAP SF + MH	WAP SF	WAP MH	KEEM	LIMF	HU
Home at unhealthy temperature (yes)	18%	19%	16%	23%	38%	21%
Asthma rates	14%	12%	18%	15%	19%	15%
Asthma – ED visit (% yes)*	13%	16%	7%	23%	20%	12%
Severe headaches (% yes)	20%	19%	23%	33%	22%	30%
Flus (% yes)	22%	23%	19%	22%	N/A	N/A
Sinus infections (% yes)	37%	36%	34%	54%	N/A	N/A
Number of days previous month physical health not good	10.3	10.2	10.3	10.9	NA	9.4
Number of days previous month mental health not good	7.1	7.0	7.4	8.9	5.6	6.0
Number of days rest/sleep last month	11.2	11.6	9.5	14.2	7.3	13.2

*Amongst respondents who reported still having asthma.

health of respondents pre-weatherization. The WAP results have been broken out into SF and MH to allow the exploration of differences between these home types.[2]

The results exhibit a potentially complicated story about health. The first observation is that all of the samples exhibit health issues. For example, all of the asthma rates are above the national average, which is about 8%. Though the LIMF sample exhibits the highest rate of homes being kept at unhealthy temperatures, the results presented in Table 3 suggest that Knoxville low-income residents in particular, with much higher rates of asthma-related emergency department (ED) visits, high rates of respiratory issues in general, and worse mental health and sleep, suffer more health issues. The major difference between the WAP SF and MH samples is that the latter have lower rates of asthma and fewer asthma-related ED visits.

5.3. Baseline material deprivation across regions and housing types

Questions were posed about home conditions, such as related to draftiness and infestations. The unexpected result about baseline housing conditions, presented in Table 4, is that overall, the MF buildings appear to be in better shape than the SF homes. The former are less drafty and less plagued by standing water and mildew, though more infested with rodents and about on par with SF homes regarding insect infestation. These findings stand in contrast to expectations that low-income, affordable MF buildings would be in worse shape across the board. There are two perspectives to assess these findings. First, in most states, particularly those in the Northeast and Midwest, the MF sector is regulated. Buildings regularly receive inspections and processes are available in some communities to tenants to complain about conditions. In most instances, weatherization of MF buildings will not proceed until they pass inspection.

Table 4
Baseline housing conditions.

Physical condition of home	WAP SF + MH	WAP SF	WAP MH	KEEM	LIMF	HU
How often home too drafty? (all to some of the time)	71%	71%	70%	83%	49%	72%
Outdoor noise? (a great deal to some)	69%	68%	72%	73%	63%	71%
How infested is home with cockroaches, other insects, and spiders? (extremely to somewhat)	25%	25%	26%	35%	20%	19%
How infested is home with mice? (extremely to somewhat)	10%	10%	13%	28%	18%	11%
Frequent mildew odor or musty smell? (%yes)	30%	31%	27%	41%	NA	N/A
How often have observed standing water in home? (always to sometimes)	20%	22%	14%	NA	9%	N/A
Have seen mold in home? (%yes)	28%	28%	28%	39%	20%	29%

Second, as noted above, the treatment sample property owners self-selected to have their buildings weatherized; within the treatment group, 20% of properties were owned by non-profits and 52% were public or government-run, which may indicate that the apartments are more likely to be subsidized and the tenants are more likely to receive additional support services and subsidies. These differences may set them apart from market-rate and other privately-owned MF buildings, which made up 28% of the treatment group. Also, the LIMF study relied on a convenience sample, and in many cases, control group buildings were recruited from owners who also had treatment buildings in the study but hadn't managed to weatherize all of their properties yet. Owners of buildings in the control group allowed their residents to be surveyed about their health, which may indicate they are more confident the surveys will not reveal serious issues – or they are more concerned about their residents than the owners who were unwilling to participate in this research. The control buildings were 38% non-profit and 10% publicly owned.

On the other hand, SF homes are rarely inspected and can easily degrade in condition if owners lack resources for home maintenance.[3] SF homes, nationally and in Knoxville, showed signs of distress and need for maintenance based on occupant survey data. A 71% majority were rated somewhat or very drafty, and residents reported high rates of home infestation, mildew, and standing water. Differing rates of mold and mildew between the SF and MF results may be partly explained by the cooler climates represented in the MF study. KEEM and HU in particular targeted homes with the highest potential for energy savings, another indication that these homes were in exceptionally poor condition at the start of the program; KEEM set a goal of achieving 25% energy savings on average across all homes. There does not appear to be any major differences between the WAP SF and MH with respect to housing conditions, which was unexpected.

Table 5 presents baseline results for nine household financial health variables. For example, respondents were asked about how hard it is to pay energy bills and about trading off buying food to pay energy bills. A very high percentage of households reported it being hard to pay energy bills pre-weatherization. The results also suggest that households place a higher priority on paying their energy bills than buying food or prescriptions.

Another unexpected result is that the MF households appear in better financial health than the SF households. They do not find it as hard to pay utility bills and are less likely to trade off paying for food or prescriptions or use short-term high interest loans to help pay utility bills. They less frequently received disconnect notices. In contrast, over half of the KEEM households reported receiving utility disconnection notices the previous year and the highest rate of not being able to afford prescriptions. The same forces from the previous section that drove a distinction in the well-being of SF versus MF occupants are likely at play here, and perhaps amplified due to laws regarding rent control and subsidized housing prices. Again, there are no substantive differences between the two WAP samples.

[2] 22% of the WAP respondents lived in mobile homes.

[3] Or, for instance, elderly households may be unable to physically perform necessary home repairs.

Table 5
Baseline household financial health.

Survey item/group	WAP SF + MH	WAP SF	WAP MH	KEEM	LIMF	HU
It is hard or very hard to pay energy bills (% yes)	75%	75%	75%	70%	38%*	66%
Received a disconnect notice past year (% yes)	39%	39%	39%	56%	26%*	44%
Did not buy food to pay energy bills (% yes)	33%	34%	28%	41%	19%*	32%
Did not pay energy bills to buy food (% yes)	27%	28%	26%	21%	19%*	16%
Received food assistance (e.g., WIC) (% yes)	56%	55%	61%	51%	60%	43%
Did not pay energy bill to fill prescriptions (% yes)	12%	12%	11%	14%	6%*	12%
Did not fill prescriptions to pay energy bills (% yes)	28%	30%	19%	33%	8%*	24%
Could not afford prescriptions (% yes)	33%	34%	29%	43%	15%	29%
Used one or more short-term, high-interest loans to pay utility bills (% yes)	19%	17%	25%	24%	9%*	21%

*Only includes households whose utility costs are not embedded in their rent.

The results thus far indicate that households eligible for low-income weatherization differ by home type with respect to basic demographics and baseline housing, health and budget conditions. The Knoxville, Southeastern urban sample of SF homes exhibit worse health, home, and financial baseline conditions. Contrary to *a priori* assumptions, the residents of MF buildings in the Northeast and Midwest are relatively healthier and in better financial shape and their buildings are in better condition. There are no substantive differences to be seen between the WAP SF and MH samples across these three themes.

5.4. Variation in material deprivation within regions and housing types

The question explored next is whether there are important differences within each of the regions as was observed between regions. To explore this question, a cluster analysis was conducted using the nine-household budget-related questions listed in Table 5. This approach allows us to better understand whether there are differences in economic baselines amongst different groups of households and then if so, whether these differences could be explained by other demographic variables. Clustering by household budget issues provides an excellent opportunity to better understand the spectrum of household budget issues beyond the homogeneous baseline income eligibility for weatherization programs. For completeness, the cluster analyses are re-done using health-related variables.

K-means cluster analysis in SPSS was used for this analysis. Initially, six clusters were specified. Our original expectations were that clusters would probably have the same average number of budget issues but illustrate different patterns of budget issues. This expectation was not supported by initial results, which showed that the most influential discriminator between clusters was the number of budget issues faced by households. In response, we re-ran analyses, reducing the number of clusters to eliminate clusters with very few households and to find clusters that emphasize those that suffer comparatively few budget issues versus a comparatively large number of issues. This process resulted in between two to three clusters per data set. The results presented in Table 6 are reported for the clusters with the fewest budget issues and the most budget issues.

The results suggest that there are large and statistically significant differences in the number of budget issues being faced by the 'best-case' and 'worse-case' clusters. The former face 1.5 or less budget issues whereas the latter face around 6 issues. Between 21 and 30% of households in the sample fall into the higher hardship cluster whereas 52–78% of the households fall into the lower hardship cluster, with the KEEM sample being an outlier with only 36% in the latter cluster. This result is consistent with the finding above that the KEEM households tended to suffer greater financial hardships overall. There were slight differences in home ownership between the WAP best and worst cases, with 8% of renters in the best-case and 16% in the worst case, whereas the KEEM program only admitted owner-occupied homes; typically it is expected that renters would face greater deprivation, but in the case of KEEM, the program's intensive targeting to those most in need seems to outweigh the lack of renter-occupied homes.

The results in Table 6 support observations made above about the LIMF sample. Over three-fourths of the LIMF households fell into the best-case cluster, which is another indication that the respondents living in the MF buildings in our sample are facing less financial hardship, as measured by our survey, than their SF and MH counterparts. There were no statistically significant differences in building ownership (private/non-profit/public) between the worse- and best-case clusters for the MF buildings, X^2 (2, n = 278) = 1.579, p = .454; none of the units were reported to be owner-occupied. However, the type of housing differed between the groups, X^2 (3, n = 367) = 20.123, p = .0002. The LIMF best-case cluster included supportive housing (3%) and double the portion of senior housing (47% vs. 23%); by contrast, the worst-case cluster was more likely to be mixed use (20% vs. 8%) or family housing (57% vs. 43%), and none of the buildings were supportive housing.

5.5. Plight of the near-elderly

Table 7 presents baseline home and health conditions for clusters with the highest financial hardship. There is a very strong underlying pattern. In addition to being more burdened economically, the worse-case clusters have much worse baseline home and health conditions.

Table 6
Indicators of financial burden – cluster analysis results.

Survey item/group	WAP Worse Case	WAP Best Case	KEEM Worse Case	KEEM Best Case	LIMF Worse Case	LIMF Best Case	HU Worse Case	HU Best Case
Cluster variables	163 (25%)	333 (52%)	72 (30%)	85 (36%)	92 (22%)	332 (78%)	201 (21%)	613 (66%)
It is hard or very hard to pay energy bills (% yes)	94%	58%***	89%	40%***	78%	24%***	90%	53%***
Received a disconnect notice past year (% yes)	63%	8%***	82%	5%***	65%	14%***	71%	28%***
Did not buy food to pay energy bills (% yes)	71%	10%***	82%	13%***	66%	4%***	72%	7%***
Did not pay energy bills to buy food (% yes)	57%	2%***	46%	6%***	84%	1%***	39%	1%***
Received food assistance (e.g., WIC) (% yes)	63%	42%***	53%	29%***	65%	64%	46%	42%
Did not pay energy bill to fill prescriptions (% yes)	98%	4%***	36%	1%***	27%	0.3%***	48%	2%***
Did not fill prescriptions to pay energy bills (% yes)	44%	1%***	96%	11%***	25%	2%***	97%	4%***
Could not afford prescriptions (% yes)	91%	8%***	93%	21%***	37%	10%***	87%	10%***
Used one or more short-term, high-interest loans to pay utility bills (% yes)	39%	4%***	33%	5%***	35%	3%***	47%	8%***
Mean number of budget issues	6.2	1.4***	6.1	1.3***	4.8	1.2***	6.0	1.5***

Pearson's Chi Square or ANOVA ***p < .001 **p < .01 *p < .05 +p < .10

Table 7
Baseline home and health conditions – cluster analysis results.

Survey item/cluster	WAP Worse Case	WAP Best Case	KEEM Worse Case	KEEM Best Case	LIMF Worse Case	LIMF Best Case	HU Worse Case	HU Best Case
Home and health conditions	163 (25%)	333 (52%)	72 (30%)	85 (36%)	92 (22%)	332 (78%)	201 (21%)	613 (66%)
Unsafe temperature (% yes)	33%	11%	62%	37%**	52%	36%**	30%	15%***
Home too drafty (% yes)	78%	62%***	89%	74%**	71%	58%**	86%	66%***
Pest infestation (% yes)	31%	20%**	46%	29%*	25%	16%+	15%	8%**
Outdoor noise (% yes)	79%	63%**	75%	65%	72%	61%+	87%	64%***
Days not enough sleep/rest last month	16.6	8.3***	17.2	11.7**	9.5	7.1+	15.9	11.7**
Worse headaches (% yes)	39%	11%***	44%	29%	36%	18%***	48%	22%***
Days bad mental health last month	12.0	3.9***	14.7	6.0***	7.0+	4.8	9.2	4.1***
Days bad physical health last month	14.9	8.0***	16.5	8.8***	N/A	N/A	13.8	7.2***

Pearson's Chi Square or ANOVA ***p < .001 **p < .01 *p < .05 +p < .10.

For example, around 40% kept their homes at unsafe temperatures compared to 8% to 22% of the best-case households identified as having less hardship. The best-case homes, even pre-weatherization, were less drafty, had fewer pest infestations, and less intrusion of outdoor noise as well. These households also reported better health – e.g., better quality sleep and rest and fewer severe headaches.

One contributing factor appears to be *age* of primary respondent (Table 8). The primary respondents living in households facing the most financial hardships are 3 to 10 years younger than their counterparts living in the better off households, which places these households firmly into the 55–64 near-elderly bracket. The worse-case cluster contained a higher portion of primary wage earners that were unable to work – the best-case had two to three times the number of retirees. It is assumed that retired households depend, at least partially, on social security payments and Medicare, which covers the costs of many prescriptions. Equivalent benefits are not available to pre-retirement, near-elderly households and in fact, the results show that more households in the worse-case clusters reported being uninsured.

As mentioned previously, this cohort faces the challenges of access to affordable health care and experience more financial hardships than those in the older age brackets. These data highlight the specific health inequities suffered by the near-elderly. One can argue that the households with the most hardships are falling through the social support systems in the United States.

5.6. Relationships to social determinants of health

Access to adequate housing and education, socioeconomic status, systemic racism and sexism, are conditions in the environment (i.e., social determinants of health) that affect a wide range of health and quality-of-life outcomes and risks. One could hypothesize that households with less education, of minority status, of larger household size, and / or those headed by a single female, would be more fully represented in the worst-case clusters. The results of a cluster analysis that included these demographic variables do not support these expectations (Table 9). About the same percentage of female primary respondents were in each cluster in each sample. Educational attainment was actually lower in the best-case clusters. The only statistically significant difference in race is found in the KEEM sample and goes against *a priori* expectations. Smaller households also were more abundant in the best-case clusters. These results need to be qualified with the knowledge that all households in all samples are in income-defined poverty levels.

5.7. Health cluster results

The results in the previous section indicate that individuals living in households that fall into worse-case clusters, as defining by budget issues, also have worse health. This section clusters primary respondents and their households by health issues. One goal is to explore whether there are also well-defined differences between the worse-off and best-off households based on health. Another goal is to explore the linkages between the two sets of clusters: do households that have the best budget situations also fall into clusters that have the best health situations? Conversely, do households that are experiencing worse budget situations also fall into clusters of households with worse health situations?

Table 10 presents the results of the health cluster analyses. Unlike the budget questions, the surveys administered during the course of the four evaluations did not contain the exact same set of health-related questions. Thus, the cluster analyses reported below were conducted using different sets of health variables. However, the overall pattern still holds – there are readily identifiable best-case and worse-case clusters with respect to health. Similarly, the analysis found that the number of households falling into the former cluster is much larger than the latter.

For example, primary respondents in the worse-case health clusters report many more days of poor physical and mental health and sleep/rest than the best-off respondents. The worse-off households also reported higher rates of headaches, flus, and sinus infections. The worse-off group reported higher rates of six conditions too: asthma, COPD, diabetes, high blood pressure, cholesterol, and arthritis. Still, reported rates are not low in the best-case clusters. For example, over 50% of respondents in the best-case cluster reported having high blood pressure and 21% reported having diabetes.

The percentage of cases that fell into both the best-case cluster with respect to budgets and with respect to health is lower than expected. For

Table 8
Age, employment status, and health care coverage – cluster analysis results.

Survey item/cluster	WAP Worse Case	WAP Best Case	KEEM Worse Case	KEEM Best Case	LIMF Worse Case	LIMF Best Case	HU Worse Case	HU Best Case
Cluster variables	163 (25%)	333 (52%)	72 (30%)	85 (36%)	92 (22%)	332 (78%)	201 (21%)	613 (66%)
Age	52	62***	56	58	49	58***	59	62**
Retired (% yes)	16%	45%***	17%	39%**	24%	38%**	27%	49%***
Unable to work (% yes)	37%	18%***	44%	20%**	N/A	N/A	35%	20%***
Have medical insurance (% yes)	76%	89%***	93%	95%	80%	89%*	91%	93%

Pearson's Chi Square or ANOVA ***p < .001 **p < .01 *p < .05 +p < .10.

Table 9
Social determinants of health – cluster analysis results.

Survey item/cluster	WAP Worse Case	WAP Best Case	KEEM Worse Case	KEEM Best Case	LIMF Worse Case	LIMF Best Case	HU Worse Case	HU Best Case
Cluster variables	163 (25%)	333 (52%)	72 (30%)	85 (36%)	92 (22%)	332 (78%)	201 (21%)	613 (66%)
Female (% yes)	72%	74%	85%	74%$^{+}$	79%	74%	82%	81%
GED or less (% yes)	44%	66%***	45%	47%	50%	59%	44%	55%**
Black/African American (% yes)	18%	14%	50%	67%	61%	49%**	76%	79%
Household size	2.7	2.1***	2.1	1.9	1.9	1.7^{+}	2.2	1.9**

Pearson's Chi Square or ANOVA $^{***}p < .001$ $^{**}p < .01$ $^{*}p < .05$ $^{+}p < .10$.

Table 10
Health clusters.

Survey item/cluster	WAP Worse Case	WAP Best Case	KEEM Worse Case	KEEM Best Case	LIMF Worse Case	LIMF Best Case	HU Worse Case	HU Best Case
Health indicators	267 (18%)	812 (56%)	63 (29%)	107 (48%)	190 (24%)	618 (76%)	69 (17%)	228 (57%)
Days not enough sleep/rest last month	18.1	1.8***	22.6	4.8***	20.0	2.9***	27.6	8.1***
Days bad mental health last month	28.0	1.6***	21.0	1.6***	18.4	1.7***	23.1	3.3***
Bad days physical health last month	20.14	3.5***	28.0	3.9***	–	–	14.0	3.4***
Worse headaches (%Yes)	41%	8.7%***	54%	20%***	43%	16%***	84%	64%**
Flus (%Yes)	23%	15%***	27%	18%	–	–	–	–
Sinus infections (%Yes)	55%	27%***	68%	42%**	–	–	–	–
Have asthma? (%Yes)	30%$^{\wedge}$	14%$^{\wedge***}$	27%$^{\wedge}$	16%$^{\wedge}$	36%	21%***	30%	24%
Have diabetes? (%Yes)	–	–	–	–	28%	21%*	–	–
Have COPD? (%Yes)	–	–	41%$^{\wedge}$	11%$^{\wedge***}$	22%	14%**	23%	13%*
High blood pressure? (%Yes)	–	–	–	–	58%	50%***	–	–
Have high cholesterol? (%Yes)	–	–	–	–	49%	36%**	–	–
Have arthritis? (%Yes)	–	–	–	–	57%	43%**	–	–
Clusters Alignment – Worse-worse; Best-best % cases	8%	33%	15%	21%	6%	63%	6%	63%
Worse Health – Best Budget % cases	5%	NA	6%	NA	15%	NA	8%	NA
Best Health – Worse Budget % cases	NA	8%	NA	11%	NA	16%	NA	13%

$^{\wedge}$Variable not used in cluster analysis. Pearson's Chi Square or ANOVA. $^{***}p < .001$ $^{**}p < .01$ $^{*}p < .05$ $^{+}p < .10$.

example, with respect to the WAP evaluation, 52% of cases fell into the best-case budget cluster and 56% of cases fell into the best-case health cluster. However, only 33% of the cases in the entire sample fell into both best-case clusters (see the row in Table 10 labeled cluster alignment). The difference is even starker with respect to the HU results: 66% of cases fell into the best-case budget cluster and 57% of cases fell into the best-case health cluster but only 36% of cases fell into both of the best-case clusters. The results are similar with respect to the worse-case clusters. For example, 22% of LIMF cases fell into the worse-case budget cluster and 24% fell into the worse-case health cluster. However, only 6% of cases fell into both worse-case clusters.

The last two rows in Table 10 indicate the percentage of cases that fall into polar opposite clusters: worse health – best budget; and best health – worse budget. These results suggest that it is more likely for a household to have good health with a bad budget than vice-versa. This observation suggests that it is much harder to overcome budget problems when one is plagued by bad health.

Table 11 supports this observation and also the previous observation about the plight of the near-elderly. Again, it is seen that the levels of retirement are higher in the best-case health clusters than the worse-case clusters. Also, primary wage earners are unable to work at a much higher rate in the worse-case clusters than those in the best-case clusters. Being unable to work, burdened with health issues and older but not of retirement age once more suggests that some low-income near-elderly households are falling through society's safety net. Countervailing this conclusion is the observation that medical insurance rates and access to prescription medicines is not uniformly lower for those in the worse-case health clusters.

6. Discussion

The results presented above indicate that prospective weatherization recipients exhibit important differences in health and material deprivation across weatherization programs, home types, and regions. Contrary to expectations, households residing in MHs do not appear to be facing more hardship than those who live in SF homes. Also contrary to expectations, households living in MF buildings appear to be facing less financial hardship and live in better housing conditions than their counterparts who live in SF and MHs. The literature suggests that as homeowners age they may find it more difficult to maintain their homes. We also hypothesize that regulatory oversight of MF buildings may, in part, explain their better condition, in addition to methodological

Table 11
Health clusters and selected demographic variables.

Survey item/cluster	WAP Worse	WAP Best	KEEM Worse	KEEM Best	LIMF Worse	LIMF Best	HU Worse	HU Best
Cluster variables	267 (18%)	812 (56%)	63 (29%)	107 (48%)	190 (24%)	618 (76%)	69 (17%)	228 (57%)
Age	54	59***	59	56^{+}	54	58*	59	57
Retired (%Yes)	20%	39%***	19%	28%	26%	46%***	23%	34%*
Unable to Work (%Yes)	41%	15%***	60%	18%***	–	–	43%	20%***
Medical Insurance (%Yes)	83%	85%	95%	93%	90%	90%	93%	89%
Health Plan Pay Some Cost of Prescriptions (%Yes)	89%	90%	100%	98%	95%	95%	94%	93%

Pearson's Chi Square or ANOVA $^{***}p < .001$ $^{**}p < .01$ $^{*}p < .05$ $^{+}p < .10$.

considerations for the LIMF study such as self-selection bias among building owners and convenience sampling.

The plight of the near-elderly is quite apparent in the cluster results. They face more financial hardships, which are strongly correlated with worse health and home conditions. The health cluster analyses support this observation. Hardships do not seem to be correlated with typical SDOH variables in our samples.

What might these results mean to weatherization program administrators? One observation is that they must take care in generalizing existing NEI evaluations to their own programs. It is not advisable to generalize SF findings to the MF sector. It is also not advisable to generalize results between different climate zones. A second observation is that weatherizing SF homes may yield higher per unit weatherized NEI benefits than weatherizing MF buildings. However, because MF weatherization is more economically efficient on a cost per weatherized unit basis to buildings, this does not mean that it is more cost efficient vis-à-vis NEIs to weatherize only SF buildings.

A third observation is that in order to maximize their programs' impacts on health and material hardship NEIs, their programs could strive to increase the percentages of worse-off households that receive weatherization. This is a difficult goal to accomplish because program eligibility is defined by income, not health or material deprivation.

One way to approach this issue is to begin to collaborate with the health care and public health sectors to refer patients to weatherization programs informally or by prescription to be covered by insurance [107]. One would expect that referrals would be for patients that are "super-utilizers" of the medical system. For example, in the U.S., just 5% of the population accounted for half of all health care spending [7]. Weatherization program administrators could set aside a percentage of their budgets to weatherize the homes of referrals, thereby avoiding administrative issues that prevent them from using factors other than income to determine program eligibility. Rules governing the use of funding from sources such as DOE's WAP and the Low Income Home Energy Assistance Program (LIHEAP) have proved a challenge in previous attempts to funnel health care funds into weatherization programs. A pilot project in Washington State concluded that the state's Matchmaker funds alone were not sufficient to address high-need homes, and that freeing up and braiding together additional funding sources would make a Weatherization Plus Health (Wx + H) program more sustainable [108]. Health care organizations might find it cost effective to pay for weatherization directly [109] as has been found in a small study in Spain [110] or to invest in healthy homes measures that would be installed on top of conventional weatherization measures. For example, weatherization crews could replace carpets with hard surfaces in homes of asthma sufferers while they are also installing air sealing and insulation measures [111]. Public health may be interested in contributing funds to prevent the occurrence of common health issues, such as trips and slips, and impacts anticipated to be caused by the climate crisis. Here we are talking about replacing stairs with ramps, installing grab bars, and also increased insulation and ventilation.

Weatherization is not the silver bullet to overcome income poverty and material deprivation and it cannot address the extensive list of health issues faced by low-income residents. But, as a program, it can provide an entrance point to low-income homes where numerous investments could be made simultaneously and cost-effectively. These investments could reduce energy use and energy burden, improve human health, and reduce material deprivation.

Lastly, limitations and qualifications about this research and the results should be noted. A strength of this research is that it is based upon data collected by several thousand resident/occupant surveys. These data were collected across the country from households living in a range of climate zones and home types. The combined databases underrepresenting renters of SF homes is a limitation. Another limitation is that the sample of affordable MF buildings was not random. It was built with the cooperation of building owners. One can argue that both limitations result in underestimating financial hardships and health issues faced by households in energy poverty. It can be hypothesized that had more SF renters and residents of affordable MF buildings with less transparent owners been included in the databases, the percentage of households in the worst-case clusters would have been higher.

Another issue relates to how generalizable these results are to the broader low-income population in the U.S. For example, is the percentage of households that fall into the worse hardship and health categories higher, lower, or the same as represented by households seeking weatherization services? Future quantitative research is needed to rigorously answer this question. However, qualitatively, numerous weatherization agencies around the country have told us that they regularly refer households that apply for energy assistance that appear to be suffering high energy burdens to their weatherization programs. Other anecdotal evidence suggests to us that the average recipient of energy assistance programs does not face the same magnitude of energy burdens as households applying for weatherization. Thus, tentatively, one could hypothesize that the average household applying for weatherization is more likely to fall into the worse-case hardship cluster than the average low-income household nationally. Still, many millions of U. S. households fall into the worse-case cluster and could greatly benefit from policy actions.

7. Conclusions

The above analyses do support a general conclusion that demographics and baseline health, home and household budget conditions differ across home types and geographic regions. The MF sample exhibited a much smaller household size and a higher percentage of non-working respondents than the SF samples. On the other hand, the SF homes appear to be in worse condition at the baseline. The core urban population in the Southeast serviced by KEEM suffer from worse health conditions at baseline. The differences between the WAP SF and MH samples are not substantial.

Perhaps the most important observation is that between 21% and 30% of each sample is comprised of households that suffer an extremely high percentage of financial hardships and poor health at baseline. These samples suffer worse health problems and live in homes in worse condition, as compared to households who suffer a small number of financial problems. Analysis of demographic data suggest that these households are populated by older adults (near-elderly) who are not of retirement age but may lack financial security and resilience. It can be argued that weatherization programs that target these types of households would yield the highest return on NEIs. Future research should explore the NEIs realized by improvements in health and reductions in material deprivation by targeting these worse off populations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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