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July 26, 2024

Via E-Filing

Ms. Lisa Felice
Executive Secretary
Michigan Public Service Commission
7109 West Saginaw Highway
Lansing, MI 48917

RE: MPSC Case No. U-21534

Dear Ms. Felice:

Please find enclosed the Accompanying Exhibits DAO-118 to DAO-124 (Part 3 of 5) for the Direct Testimony of Justin Schott on Behalf of Soulardarity and We Want Green, Too, along with proof of service for electronic filing in the above-referenced matter. Please do not hesitate to contact me with any questions or comments.

Sincerely,

Mark N. Templeton, *pro hac vice*
6020 S. University Avenue
Chicago, IL 60637
Phone: (773) 702-9611
Email: templeton@uchicago.edu

xc: Parties to Case No. U-21534

7/19/24, 7:50 AM

Hurricane Beryl caused at least 20 Houston-area deaths, with half power outage-related – Houston Public Media



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Hurricane Beryl caused at least 20 Houston-area deaths, with half power outage-related

The local death toll from the July 8 storm could continue to climb as medical examiner's offices continue to investigate.

Adam Zuvanich (<https://www.houstonpublicmedia.org/articles/author/adam-zuvanich/>) | July 18, 2024, 5:15 PM



(https://www.houstonpublicmedia.org/articles/news/hurricane/2024/07/08/492833/houston-power-outages-hurricane-beryl-centerpoint/attachment/powerline_cypress_beryl/)

Colleen DeGuzman/Houston Public Media

A tree was blown into powerlines by Hurricane Beryl in a Cypress neighborhood.

Hurricane Beryl has caused at least 20 deaths in the Houston area, and widespread power outages during and after the July 8 storm contributed to half of those fatalities.

More than 2.2 million homes, schools and businesses – representing about 80% of the electricity customers served by CenterPoint Energy – lost power at the peak of the Category 1 hurricane that was particularly damaging because it passed almost directly over Houston (<https://www.houstonpublicmedia.org/articles/news/hurricane/2024/07/12/493415/hurricane-beryl-path-houston-damaging-category-1-hurricane/>). Hundreds of thousands remained without electricity more than a week afterward, and there still were about 10,000 outages as of Thursday afternoon.

Six of the 13 storm-related deaths in Houston and Harris County were caused by heat exposure tied to a power outage, according to information released by the Harris County Institute of Forensic Sciences (https://ifs.harriscountytexas.gov/Portals/IFS/Documents/Beryl_Storm_Related_Deaths_06.pdf). Chief investigator John Florence of the Galveston County Medical Examiner's Office said Thursday that electricity losses contributed to all three of the confirmed, hurricane-related deaths there, adding that doctors were still working to determine the causes of death of three other people who were found in homes without power.

In Matagorda County, where the hurricane made landfall before proceeding north through Houston, a 60-year-old Bay City man who was bed-ridden and paralyzed from the waist down died from heatstroke on the evening of July 8, in a home that lost power, according to county spokesperson Mitch Thames.

"It's tragic," Thames said. "Our hearts and prayers go out to the family."

RELATED: Lieutenant Governor Dan Patrick fronts special senate committee after CenterPoint's lackluster Beryl response (<https://www.houstonpublicmedia.org/articles/news/energy-environment/2024/07/18/494018/lieutenant-governor-dan-patrick-fronts-special-senate-committee-after-centerpoints-lackluster-beryl-response/>)

The Houston-area death toll from Beryl – which according to the Associated Press killed at least 11 people in the Caribbean before swirling its way through the Gulf of Mexico and into Texas – could continue to climb in the aftermath of the storm.

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Scott Yao, a spokesperson for the Fort Bend County Medical Examiner's Office, said Thursday that no storm-related deaths there had been confirmed – yet. The eye of the storm passed over the county, which is southwest of Houston.

"There might be some, but we're still gathering information right now," Yao said.



(https://www.houstonpublicmedia.org/?attachment_id=494071)

Houston Police Department

Russell Richardson, 54, was a Houston Police Department employee who drowned during Hurricane Beryl on July 8, 2024.

Three of the storm victims in Harris County drowned, with two Houston men, including Houston Police Department employee Russell Richardson, getting caught in vehicles that were submerged by floodwaters. Two other Harris County residents were killed by fallen trees on the day of the hurricane, and two Houston men died in the days that followed when they fell while trimming damaged trees.

All three of the storm-related deaths that have been confirmed in Montgomery County, which is north of Houston, were caused by fallen trees on July 8, according to Judge Wayne Mack, the Justice of the Peace for Precinct 1. Two of the victims were apparently homeless and inside a tent in Magnolia, Mack said, and another man who died was struck by a falling oak tree while riding his tractor in the eastern part of the county.

RELATED: Some Houston ISD campuses damaged by Hurricane Beryl might not be ready for start of school year
(<https://www.houstonpublicmedia.org/articles/news/education-news/hisd/2024/07/17/493963/some-houston-isd-campuses-damaged-by-hurricane-beryl-might-not-be-ready-for-start-of-school-year/>)

Mack said Richard Ross, 41, was on his way home after using his tractor to help clear a nearby road.

"He was being a good Samaritan," Mack said. "He was helping neighbors clear trees from the roadway so EMS and fire could get through. The storm wasn't quite over."

Ross was the youngest hurricane victim in the Houston area, according to local authorities. The other 19 people were age 50 or older, and 13 of the victims were in their 60s or 70s.

Below is a list of the 20 storm-related deaths that have been confirmed by Houston-area authorities:

Name	Age	Date of death	Location	Cause of death
Harris County				
Maria Loreda	73	July 8	Houston	Blunt force injuries (crushed by fallen tree)
Russell Richardson	54	July 8	Houston	Drowning (submerged vehicle)
Sara Elizabeth Elston	76	July 8	Clear Lake	Complications of drowning (sunken boat)
Johnnie Courtney	77	July 8	Houston	Drowning (submerged vehicle)
Jay Michael Taylor	53	July 8	Humble	Mechanical asphyxia with blunt trauma (pinned under collapsed house and fallen tree)
Charles Richard Anderson Sr.	76	July 10	Pasadena	Hyperthermia (heat exposure due to electricity loss)
Candie York	50	July 10	Houston	Hyperthermia (heat exposure due to electricity loss)
Oscar Rodriguez	78	July 10	Houston	Hyperthermia (heat exposure due to electricity loss)
James Edward Butcher	75	July 11	Pasadena	Hyperthermia (heat exposure due to electricity loss)

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Bryan Keith Taylor	66	July 11	Houston	Hyperthermia (heat exposure due to electricity loss)
Pamela Jarrett	64	July 11	Houston	Hyperthermia (heat exposure due to electricity loss)
Tomas Fermin Vergara	59	July 12	Houston	Blunt trauma (fell from ladder while cutting tree limbs)
William Correrias	53	July 14	Houston	Blunt force injuries (fell while trimming damaged tree)
Galveston County				
Judith Greet	71	July 8	Crystal Beach	Complications of COPD and lack of supplemental oxygen due to electricity loss
Leroy Lyons	77	July 10	Galveston	Cardiovascular disease (heat exposure due to electricity loss was contributing factor)
Michael Lahr	71	July 11	Galveston	Cardiovascular disease (heat exposure due to electricity loss was contributing factor)
Matagorda County				
Charles Yañez	60	July 8	Bay City	Heatstroke (was in home that lost electricity)
Montgomery County				
Ethel Carter	66	July 8	Magnolia	Blunt force trauma (struck by fallen tree)
Michael Privett	52	July 8	Magnolia	Blunt force trauma (struck by fallen tree)
Richard Ross	41	July 8	East Montgomery County	Blunt force trauma (struck by fallen tree)

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Adam Zuvanich
REPORTER

([http://mailto:azuvanich@houstonpublicmedia.org](mailto:azuvanich@houstonpublicmedia.org))

Adam Zuvanich writes locally relevant digital news stories for Houston Public Media. He grew up in the Houston area and earned a journalism degree from the University of Texas before working as a sportswriter in Austin, Lubbock, Odessa, St. Louis and San Antonio. Zuvanich returned home to Houston and made...

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How Blackouts during Heat Waves Amplify Mortality and Morbidity Risk

Brian Stone, Jr.,* Carina J. Gronlund, Evan Mallen, David Hondula, Marie S. O'Neill, Mayuri Rajput, Santiago Grijalva, Kevin Lanza, Sharon Harlan, Larissa Larsen, Godfried Augenbroe, E. Scott Krayenhoff, Ashley Broadbent, and Matei Georgescu



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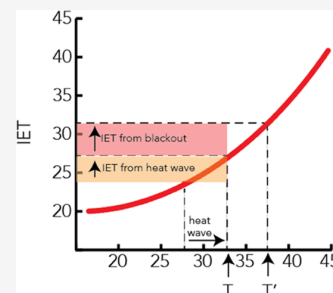
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Supporting Information

ABSTRACT: The recent concurrence of electrical grid failure events in time with extreme temperatures is compounding the population health risks of extreme weather episodes. Here, we combine simulated heat exposure data during historical heat wave events in three large U.S. cities to assess the degree to which heat-related mortality and morbidity change in response to a concurrent electrical grid failure event. We develop a novel approach to estimating individually experienced temperature to approximate how personal-level heat exposure changes on an hourly basis, accounting for both outdoor and building-interior exposures. We find the concurrence of a multiday blackout event with heat wave conditions to more than double the estimated rate of heat-related mortality across all three cities, and to require medical attention for between 3% (Atlanta) and more than 50% (Phoenix) of the total urban population in present and future time periods. Our results highlight the need for enhanced electrical grid resilience and support a more spatially expansive use of tree canopy and high albedo roofing materials to lessen heat exposures during compound climate and infrastructure failure events.

KEYWORDS: extreme heat event, infrastructure failure, heat-related mortality, climate change, urban heat management, compound climat, infrastructure failure events



INTRODUCTION

The incidence of electrical grid failure or “blackout” events is increasing across the United States. Since 2015, when the U.S. Energy Information Administration commenced monthly reporting on major blackout events (defined as power outages lasting more than 1 h and impacting more than 50,000 customers), the number of such events nationwide has more than doubled, increasing by 151% between 2015–16 and 2020–21 (Figure 1). The majority of these events occurred during the summer months, when the annual demand for electricity is maximized and electrical grids are further stressed by extreme weather in the form of heat wave, hurricane, tornado, and wildfire events. Prior work finds the concurrence in time of two or more extreme weather events, such as a hurricane and heat wave, also to be on the rise,¹ further enhancing potential health impacts of compound climate and infrastructure failure events. Most recently, in June of 2021, electrical grid failures associated with a heat wave of historical intensity in the Pacific Northwest of the United States resulted in a loss of power to tens of thousands of customers, at least 600 excess deaths, and more than 3500 emergency department visits for heat illness.^{2–4} Persistent drought conditions in the Western United States are further reducing the capacity of regional electrical generation and distribution systems to manage surges in electrical demand in this and other regions confronting climate-driven pressures on critical infrastructure.⁵

Despite a rising incidence of electrical grid failures, few studies have sought to directly assess the public health risks of compound climate and infrastructure failure events. Here, we estimate heat-related mortality and morbidity resulting from heat wave events of historical duration and intensity occurring simultaneously with simulated blackout conditions for the full urban populations of Atlanta, Georgia; Detroit, Michigan; and Phoenix, Arizona. Building on prior work modeling building-interior heat exposures resulting from concurrent heat wave and blackout events across these three cities,^{7,8} in this paper, we estimate the likelihood of health impacts through the development of an individual-level heat risk model accounting for hourly indoor and outdoor heat exposures and person-level risk characteristics. We then simulate the influence of urban heat management strategies on heat-related mortality and morbidity, as well as the impact of more intense heat wave events projected with continued global scale warming in future time periods.

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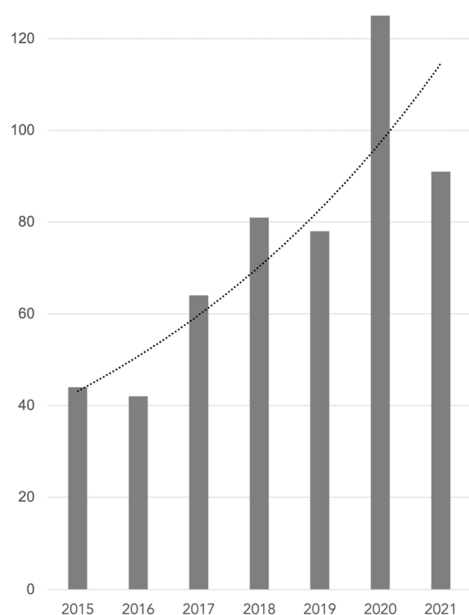


Figure 1. Total number of major electrical grid failure events for U.S. power utilities (2015–2021).⁶

This paper reports results from the Three-City Heat and Electrical Grid Failure Adaptation Study (3HEAT), which is focused on compound climate and infrastructure failure events in three large U.S. cities characterized by distinct regional climates and population characteristics. The cities of Atlanta, Georgia; Detroit, Michigan; and Phoenix, Arizona were selected to include three distinct climate zones in which approx. 75% of the U.S. population resides, as well as variable demographic and climatic risk factors for heat illness. [Table 1](#)

Table 1. Key Characteristics for Each City of Relevance to Heat Vulnerability

attribute	Atlanta	Detroit	Phoenix
population size ⁹	420,000	713,770	1,445,630
male population ⁹	49%	48%	51%
population > 65 years of age ⁹	10%	12%	9%
nonwhite population ⁹	62%	89%	34%
persons in poverty ⁹	26%	38%	23%
central air conditioning in home	94%	53%	99%
mean summer daily temperature range ¹⁰	21–32 °C (71–89 °F)	17–28 °C (63–82 °F)	28–41 °C (82–105 °F)
climate zone ¹¹	mixed-humid	cold	hot–dry

presents key characteristics for each city of relevance to heat vulnerability. We limit our study to three cities due to the extensive data inputs required to model both outdoor and building-interior heat exposures for more than 2.5 million residents across the three cities.

A collaboration between Arizona State University, the Georgia Institute of Technology, and the University of Michigan, the 3HEAT study examines three questions largely

unaddressed by the literature on climate and health: (1) How does individual heat exposure change during concurrent heat wave and blackout events, relative to heat wave conditions with a fully operational electrical grid? (2) How do estimated public health impacts, including heat-related mortality and morbidity, change during concurrent heat wave and blackout events, relative to heat wave conditions with a fully operational electrical grid? (3) How do these estimated health impacts change in response to citywide urban heat management planning and to a growing intensity of heat wave conditions over time?

The first of these three study questions requires that we model heat exposure for both outdoor and building-interior environments. Established approaches to estimating health impacts associated with heat exposure are typically reflective of outdoor temperatures only, often measured at a single location, such as a metropolitan airport weather station, and therefore do not account for variable exposures for individuals in different locations of the city.¹² Given that a grid failure has only limited impacts on outdoor temperatures but may substantially elevate building-interior temperatures, a reliance on outdoor temperature alone also fails to capture the changing nature of heat exposure during concurrent heat wave and blackout events.

To address this limitation of conventional approaches to assessing heat risk, we derive for this study a heat exposure metric referred to in prior work as “individually experienced temperature” or IET.^{13,14} IET provides a metric of human heat exposure that accounts for exposure changes as individuals move between indoor and outdoor environments during a 24 h period. Under blackout conditions, indoor heat exposures will rise, particularly for individuals who would otherwise have access to mechanical air conditioning in the home when the electrical grid is operational. The result is a rise in their IET and subsequent heat risk. We report the magnitude of this exposure change for different building types in a series of prior papers.^{7,8,15}

To assess how elevated heat exposures during concurrent heat wave and blackout conditions may impact health outcomes, we devise a novel approach to estimating individual heat risk. Established exposure-response functions widely used in heat risk assessment are responsive to outdoor temperature measurements only, often derived from the same single location for a full urban population.^{16–19} Using urban-scale climate models, in combination with building energy simulation tools, we spatially disaggregate heat exposure to the level of the residential parcel, accounting for both how ambient temperatures vary across the urban environment and how these environmental temperatures influence building-interior temperatures for different classes of residential structures.

Health impact exposure-response functions for IET—reflective of both outdoor and building-interior temperatures—are not currently available. Therefore, we derive an “analog” outdoor temperature (T') for each resident through the statistical association between estimated building-interior temperatures and a single airport weather station temperature (T) for every hour of the day during heat wave conditions with an operational electrical grid (the normal operating conditions captured by published exposure-response functions). Based on this statistical association, we then adjust outdoor temperatures to scale with rising IET (due to building-interior temperatures) during blackout conditions, yielding an analog outdoor

temperature that can be used with established exposure-response functions for heat-related mortality and morbidity. The result is an outdoor temperature metric (T') adjusted to reflect an elevated indoor heat burden during blackout conditions (Figure 2).

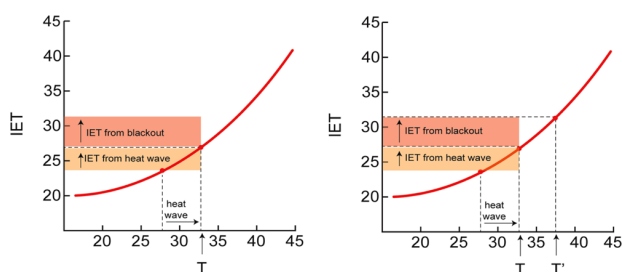


Figure 2. Estimation of “analog” temperature (T'). Weather station temperature (T) underestimates individually experienced temperature (IET) during blackout conditions (left panel). T' adjusts T to capture both outdoor and building-interior heat burden reflected in IET (right panel). The red curve depicts the statistical association between IET and T under heat wave conditions with an operational grid, measured in celsius.

We address the last of these three questions—How do health impacts change in response to urban heat management strategies and future period warming?—through the re-simulation of IET in response to a modified built environment (in the form of enhanced tree canopy and high albedo roofing materials). The modified built environment has the general effect of lowering the analog air temperatures used to estimate individual heat risk. However, more intense heat waves in future time periods result in elevated analog temperatures, serving to enhance heat risk.

MATERIALS AND METHODS

Our research accomplished two principal tasks: (1) estimation of individually experienced temperature (IET) and (2) estimation of population health impacts from a concurrent heat wave and blackout event. Each of these tasks is described in turn.

Individually Experienced Temperature (IET). Estimation of IET required three sets of data inputs: (1) modeled outdoor ambient temperatures, (2) modeled building-interior temperatures, and (3) daily activity patterns for each resident, allowing for the individual assignment of location-specific outdoor and building-interior temperatures by time of day. We simulated outdoor and building-interior temperatures during historical heat wave events in each city with the Weather Research and Forecasting (WRF) model and the U.S. Department of Energy EnergyPlus building energy model (version 8.6), respectively. Historical heat wave events were classified as any 5 day period between 1980 and 2009 in which daily average air temperatures met or exceeded the 97.5th percentile of daily average temperature. Subsequently, the 90th percentile heat wave from each 30 year period in each city was selected and considered representative of the base period climate. The resulting heat wave periods identified were August 14–18, 1995 (Atlanta); June 15–19, 1994 (Detroit); and July 20–24, 2006 (Phoenix). Projected future heat waves representative of ~2055 (mid-century) and ~2085 (late century) were identified in the same way (i.e., 90th percentile

5 day heat waves in the global climate model output²⁰) and subsequently simulated with WRF.

To capture the dynamics of an urban setting, the building effect parameterization (BEP) multilayer urban canopy model was selected in WRF. High-resolution (1 km² grid spacing for the inner domain) two-way coupled WRF + BEP simulations were carried out using a nested grid configuration, enabling the downscaling of the large-scale synoptic flow from the coarsest outer grids to the finest inner grids across each of the three study regions. We made use of RCP 8.5 for both mid- and late-century time periods to assess the highest emission scenarios and to incorporate continuing uncertainty over achievable global emission reductions this century. Trees are represented in WRF-BEP as a simplification of the BEP-Tree model.²¹ Tree shading of impervious surfaces (streets and building walls) is calculated according to Beer’s law, accounting for forward transmission of shortwave radiation through leaves. For simplicity and to conserve energy, all shortwave radiation intercepted by tree foliage is assumed to be converted to transpiration and therefore does not impact air temperature via sensible heat flux. This represents a maximum impact scenario of well-watered trees on air temperature. In the current formulation, trees do not impact wind or longwave radiation, both factors that can slightly counter the shading and transpiration cooling effect. A more complete description of the tree implementation is given in Stone et al.⁷

To simulate building-interior exposures, we adapted the EnergyPlus model to simulate indoor temperatures within distinct residential building types, including 1-story, single-family houses; 2-story, single-family houses; and multistory apartment buildings. Building prototype parameters, including age, size, construction materials, and insulation values, were selected to reflect the local residential building stock in Atlanta, Detroit, and Phoenix. In addition to building prototype characteristics, the building energy model simulations were driven by the ambient weather output at the neighborhood (1 km) scale derived from the WRF model runs in each city. The location-specific effects of tree shading and shading from adjacent buildings were not captured in our modeling. For a complete description of our approach to building-interior temperature simulation, please see Stone et al.⁷

Individual hourly exposures to outdoor and building-interior temperatures were constructed from a synthetic population dataset for each city and national time–activity pattern survey data. The unavailability of location-specific identifiers for individuals in U.S. Census data requires that “synthetic” population datasets be developed for a range of demographic and economic analyses linking individual residents to geographic boundaries more disaggregated than Census blocks. For this study, we acquired synthetic population data from RTI International (RTI Synthpop), which depicts each resident of a Census block group as a randomly positioned point within the block group boundaries and assigns to these points demographic characteristics including age, sex, race, and income. As the total number of residents per block group is reported by the U.S. Census Bureau, but not the specific address of each resident, each person included in the RTI Synthpop digital map must be assigned to a specific address, enabling a set of building characteristics to be associated with each resident.

To carry out this task, we made use of a geographic information system (ESRI ArcGIS) to assign each resident to a unique address and residential structure through the creation

Table 2. Exposure Scenarios

scenario name	time period	electrical grid status	scenario conditions
power on	present day	operational	thermostat set point of 24 °C (75 °F) for residential structures with central AC systems.
power off	present day	nonoperational	no mechanical cooling for any structures for 48 h; power restoration sequenced by proximity to electrical substations over 72 h.
street trees	present day	nonoperational	all roadways with exception of interstate highways assumed to be 50% covered by tree canopy (tree characteristics are broadly representative of each region).
cool roofs	present day	nonoperational	roof material albedos for all buildings set at 0.88.
mid century	2050s	nonoperational	outdoor temperatures representative of a modeled heat wave in ~2055 in each city for the RCP 8.5 scenario; no heat management strategies in effect.
late century	2080s	nonoperational	outdoor temperatures representative of a modeled heat wave in ~2085 in each city for the RCP 8.5 scenario; no heat management strategies in effect.

Table 3. Ambient Heat Wave Temperatures and Mean IET under the Power On and Power Off Scenarios by City

attribute	Atlanta	Detroit	Phoenix
heat wave temperature range	25–36 °C (77–97 °F)	22–35 °C (72–95 °F)	32–45 °C (90–113 °F)
mean IET for Power On scenario	25.9 °C (78.7 °F)	25.3 °C (77.5 °F)	26.3 °C (79.3 °F)
mean IET for Power Off scenario	28.1 °C (82.5 °F)	26.9 °C (80.4 °F)	32.7 °C (90.8 °F)
mean IET for Street Tree scenario	27.6 °C (81.7 °F)	26.5 °C (79.7 °F)	32 °C (89.6 °F)
mean IET for Cool Roof scenario	27.5 °C (81.5 °F)	26.3 °C (79.3 °F)	31.4 °C (88.6 °F)

of a circular buffer around each multifamily building or single-family house. First, any synthetic persons located within a 500-foot radius of a high-rise multifamily building (defined as more than five stories in height) were assigned to that building. Second, any synthetic persons located within a 250-foot radius of a low-rise multifamily building (defined as five stories in height or less) were assigned to that building. Lastly, all remaining synthetic persons were assigned to the nearest single-family home. This procedure resulted in the assignment of specific residential structure characteristics, including building-interior temperatures, to each resident of the three cities.

Individual time–activity patterns were derived from the American Time Use Survey (ATUS), conducted annually by the U.S. Bureau of Labor.²² We extracted time use data from respondents in each of the three study cities during the period 2004–2015. There were 2958 respondents that met the inclusion criteria and completed a total of 59,774 logged activities on the survey. Each activity was assigned to one of five location categories based on the nature of the recorded activity code, using guidance from Hoehne et al.²³ The location categories include indoor home, indoor away (e.g., at a workplace), outdoor home, outdoor away, and vehicle. The time–activity profiles of ATUS respondents from each respective city were then assigned to each synthetic resident based on common attributes between the two datasets, including age, sex, occupation, and income. In assigning time–activity profiles to synthetic residents of each city, we drew randomly from the ATUS respondents who were assigned to the same combination of age, sex, occupation, and income categories. IETs for each hour were calculated for each synthetic person as the proportion of time spent in each of the five environmental conditions (indoor home, indoor away, outdoor home, outdoor away, vehicle) multiplied by the temperature in each of the respective environment and then summed for each hour of the day.

Building-interior temperatures were simulated in response to ambient heat wave conditions for two sets of electrical grid scenarios for the same 5 day heat wave period: (1) the grid is

assumed to be fully operational (Power On) and (2) the grid is assumed to be fully nonoperational (Power Off) across the municipal extent of each city. For the Power On scenario, we made use of a mechanical air conditioning prevalence model to estimate the probability that central air conditioning, partial air conditioning (window AC units), or no mechanical air conditioning is available within each residential structure. Requiring as input parcel tax records reporting the home value, owner-occupied status, housing age, and housing structure type, combined with data on cooling-degree days within each city, AC prevalence was estimated with a regression model found in prior work to predict the presence of central or partial AC systems at the parcel level with a model accuracy of 84 and 82%, respectively.²⁴ Building-interior temperatures during the Power On scenario are responsive to the type (or absence) of air conditioning system assigned to each structure. For structures with central AC systems, we assumed a constant set-point temperature of 24 °C during Power On conditions.⁷

For all scenarios in which the electrical grid is nonoperational, we assume 48 h of complete blackout conditions for every residential structure across the three cities and then restore power over the remaining 72 h of the heat wave based on the proximity of each structure to electrical grid substations. Electrical power is assumed to be restored to residential structures most proximate to these substation nodes first, with structures more distant from these nodes assigned a lower temporal priority in power restoration.²⁵ In prior work, we found the median duration of recent U.S. blackout events impacting 1 million customers or more to be approx. 120 h, consistent with the large-scale events simulated herein.⁸ During blackout conditions, building-interior temperatures are responsive to localized outdoor temperatures and the specific characteristics of the building prototype (e.g., single vs multistory). For all residential structure types, windows are assumed to be opened at any time during concurrent heat wave and blackout conditions that ambient ventilation would have the effect of lowering indoor temperatures. Under the Power Off scenario, all residents of each city were assumed to remain in their residential structures (the indoor home location) due

Table 4. Details on Exposure-Response Functions

study	city and time period	health outcome	age and sex	threshold high T (°C)	RR for high vs threshold T	ln(RR) for 1 °C increase
Gasparrini et al. 2015 ¹⁸	Atlanta, 1985–2006	nonexternal all-cause mortality	all	25.6–32.5	1.064	0.0129
Gasparrini et al. 2015 ¹⁸	Detroit, 1985–2006	nonexternal all-cause mortality	all	23.9–31.3	1.58	0.110
Gasparrini et al. 2015 ¹⁸	Phoenix, 1985–2006	nonexternal all-cause mortality	all	33.3–40.6	1.21	0.0539
Wquist et al. 2016 ²⁷	Atlanta, 1993–2012	heat-related ED visits	all	27–32	4.59	0.305
Petitti et al. 2016 ¹⁷	Phoenix, 2000–2011	heat-related ED visits	all	33–40	3.50	0.179

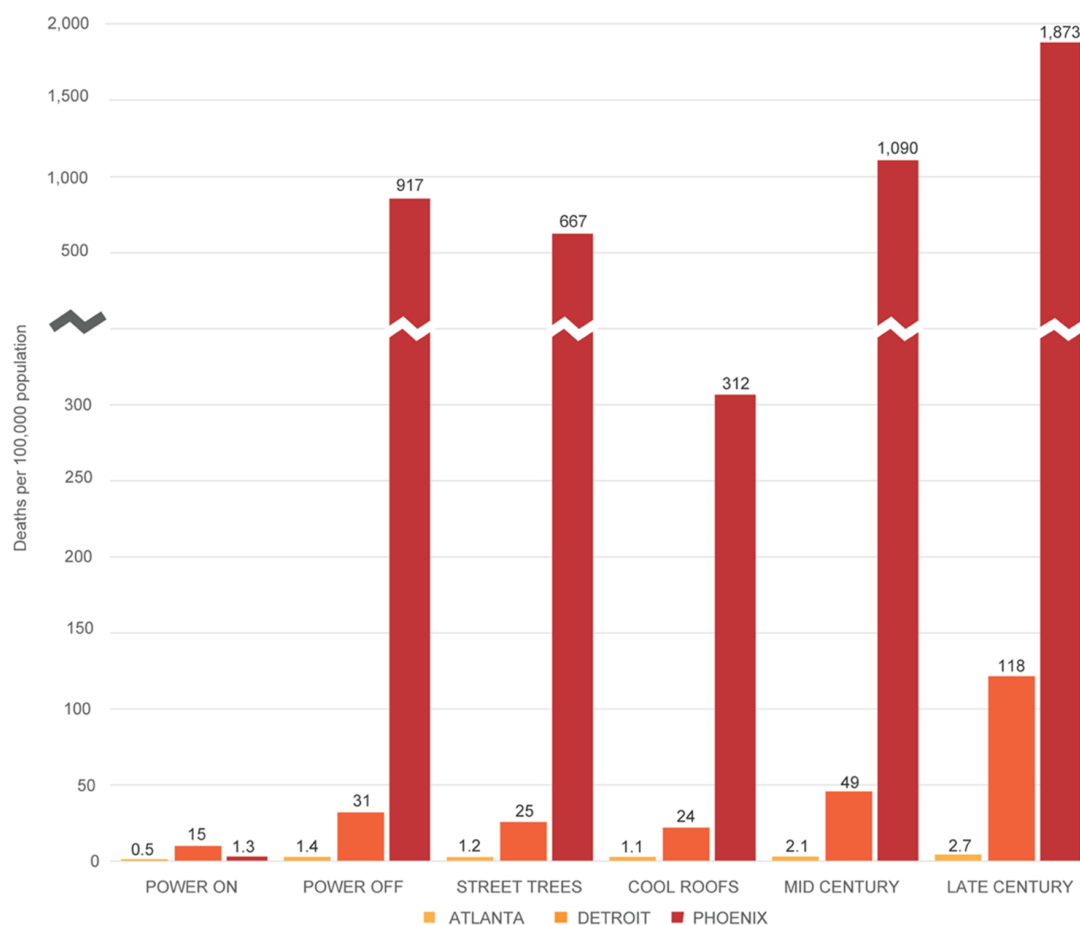


Figure 3. Rate of heat mortality during concurrent 5 day heat wave and blackout events in Atlanta, Detroit, and Phoenix by scenario. The Street Trees, Cool Roofs, Mid Century, and Late Century scenarios reflect blackout conditions.

to the assumed inoperability of transportation systems and blackout conditions at the workplace.

IET is estimated for each synthetic resident based on daily time–activity patterns, simulated outdoor and building-interior temperatures associated with each activity, and outdoor and building-interior temperatures associated with variable heat exposure scenarios. Each exposure scenario is detailed in Table 2. We report ambient heat wave temperatures and mean IET under the Power On and Power Off scenarios by city in Table 3 and illustrate the distributions of these scenarios in Supporting Information Figure S1.

Health Impact Assessment. We estimated the probability of heat-related mortality or morbidity for each resident during the 5 day heat wave and in response to each of the scenario

conditions presented in Table 2. The health impact assessment consists of the following steps:

Step 1: Hourly outdoor temperatures from the nearest airport weather station in each city were downloaded from the Integrated Surface Database²⁶ for a 10 day period, including five consecutive days of historic heat wave conditions and five subsequent days not characterized by heat wave conditions. We make use of airport weather station data to match the meteorological data used in the derivation of RR for emergency department visits in Atlanta and Phoenix and most commonly used to derive RR for heat-associated mortality.

Step 2: For both the extreme heat and nonextreme heat days, average daily IETs were joined with average daily airport

temperatures for each resident by day (i.e., each day's average outdoor temperature was associated with an individual's estimated average IET for the same day).

Step 3. We then used the derived IET-outdoor temperature associations for unique combinations of building type, age, sex, income, and occupation to estimate "analog" outdoor temperature (T') or the inflated temperature corresponding to blackout IET values, for these building type and demographic combinations. To do so, a mixed effect linear regression was fit to model IET as a function of outdoor airport temperature and building characteristics, age, sex, income, and occupation as follows

$$[\text{IET}]_{\text{pd}} = \beta_0 + \beta_1 X_{\text{pd}} + \beta_2 T_{\text{pd}}$$

where p indexes persons, d indexes days, and X is a vector of individual characteristics (age, income, sex, occupation categories, housing categories).

The regression equation was rearranged to estimate an analog daily T , or T' , for each person's daily IET

$$T'_{\text{pd}} = \frac{1}{\beta_2} \times [\text{IET}]_{\text{pd}} - \frac{\beta_0 + \beta_1 X_{\text{pd}}}{\beta_2}$$

In this resulting equation, T' for each person for a given IET is the estimated rate at which T increases with each degree of IET, or $\frac{1}{\beta_2}$, and $\frac{\beta_0 + \beta_1 X_{\text{pd}}}{\beta_2}$ is a constant, or intercept, specific to that type of person.

Step 4. We next substituted T' for airport temperature in exposure-response functions to capture the effects of blackout conditions on individual heat risk. Gasparrini et al.¹⁸ derived nonlinear exposure-response functions for heat-related mortality for a large number of global cities, including Atlanta, Detroit, and Phoenix. Exposure-response functions for heat-related emergency department (ED) visits are only available for two of our three study cities: Atlanta²⁷ and Phoenix.¹⁷ Details on each of these exposure-response functions are provided in Table 4.

Step 5. The total daily burdens were calculated as the product of the age/sex/race category population and the category-specific incidence rate obtained for each health outcome: mean daily all-natural-cause mortality²⁸ and cause-specific ED visits.²⁹ The attributable fractions, derived from the nonextreme heat relative risks (RRs) for each person-day, were then multiplied by the total daily burdens. This estimated the fractional burdens for each person-day on a nonextreme heat day.

Step 6. For the extreme heat days in each city, the heat-attributable burdens were subtracted from the total daily burden to derive the "baseline health burden" or non-heat-associated burden for each age/sex/race category.

Step 7. The extreme heat days in our study were unusually high-temperature events and may therefore have resulted in mortality and morbidity beyond the annual rates observed in the total health burden data. Therefore, rather than using the attributable fractions from step 5, which assume that the attributable burdens were fractions of observed total burdens, we multiplied the extreme-heat-event RRs by the baseline burdens from step 6 to estimate the extreme-heat-event-attributable burdens for each person-day. Thus, the baseline burdens from step 6 allow estimated attributable burden to exceed the observed historical total burden (please see Supporting Information Figure S2). As a final step, we sum

the heat-attributable burdens over the 5 day heat wave to estimate the total risk of heat-related mortality or morbidity. Estimated aggregate risks are limited to a maximum of 1 per person.

RESULTS AND DISCUSSION

We find a substantial increase in heat-related mortality and morbidity across each of the three cities with a loss of electrical power during heat wave conditions. As presented in Figure 3, the rate of mortality (per 100,000 population) under conditions of an operational electrical grid (Power On) shows substantial variation between Atlanta and Phoenix, cities with a citywide prevalence of central AC in residential structures of greater than 90%, and Detroit, which exhibits a population rate of AC prevalence of less than 60%.⁸ During a heat wave event of historical intensity with an operational electrical grid, Detroit experiences a rate of heat-related mortality many-fold greater than the cities with high AC prevalence due to a lower adaptive capacity for heat in the form of mechanical cooling.

The estimated rate of heat-related mortality (per 100,000 population) for each city during simulated heat wave conditions with an operational electrical grid (Power On scenario) is 0.5 in Atlanta (total = 2), 15 in Detroit (total = 107), and 1.3 in Phoenix (total = 19) (Note: Total heat-related deaths are not reported in Figure 3). In addition to AC prevalence, the relatively low level of mortality in Atlanta can be attributed to maximum heat wave temperatures 9 °C lower than observed in Phoenix, which reaches 45 °C in the late afternoon.

We find a citywide loss of electrical power during a 5 day heat wave of historical intensity (Power Off scenario) to more than double the estimated rate of heat mortality in Atlanta and Detroit, where maximum outdoor and building-interior temperatures reach about 35 °C in the late afternoon and remain above a daily minimum temperature of 25 °C (Atlanta) or 22 °C (Detroit). In Phoenix, where the lowest daily high temperature over the 5 day heat wave is 43 °C and daily minimum temperatures average 32 °C, the rate of heat-related mortality increases by about 700% relative to the Power On scenario, reflecting the extremity of heat exposures in a desert city in the absence of mechanical AC. As reported in Figure 3, the estimated rate of heat-related mortality for the Power Off scenario in Phoenix is 917 (approximate total = 13,250 deaths), which approaches 1% of the synthetic population. The estimated rate of heat-related mortality for comparable 5 day events in Atlanta and Detroit is 1.4 (total = 6) and 31 (total = 221), respectively.

Heat management strategies in the form of street trees and cool roofing measurably reduce heat-related mortality across the three cities, particularly in Phoenix. An increase from present-day tree canopy shading of roadways to an average of 50% across all streets is found to reduce the estimated rate of heat mortality by 14 and 19% in Atlanta and Detroit, respectively, and by 27% in Phoenix. In response to the installation of highly reflective cool roofs for all building types citywide, the rate of heat-related mortality falls by 21% in Atlanta, 23% in Detroit, and 66% in Phoenix. We attribute the disproportionate benefits of cool roofing in Phoenix to the extremity of temperatures during heat wave conditions, during which rates of evapotranspiration from trees may be reduced, lessening the cooling effects of tree canopy.³⁰

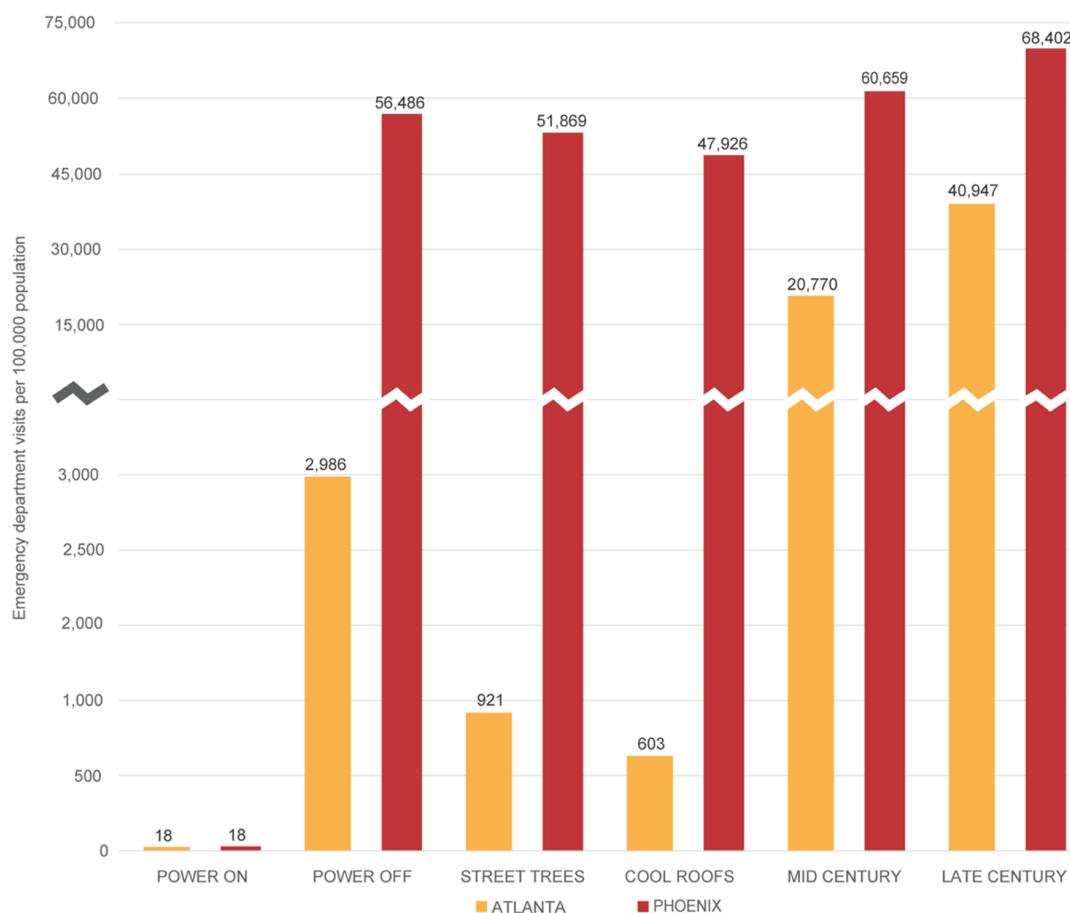


Figure 4. Emergency department visits per 100,000 population during concurrent 5 day heat wave and blackout events in Atlanta and Phoenix by scenario. The Street Trees, Cool Roofs, Mid Century, and Late Century scenarios reflect blackout conditions. No published exposure-response function for emergency department visits is available for Detroit.

Projected warming by middle (~2055) and late (~2085) century under the RCP 8.5 global emissions trajectory further amplifies estimated heat-related mortality, particularly by late century. In response to a mid-century heat wave of comparable intensity to the historical event modeled in the base period, the rate of heat-related mortality increases by 50% in Atlanta, 58% in Detroit, and 19% in Phoenix relative to the base period. By late century, the rate of heat-related mortality increases by 93%, 281%, and 104% in Atlanta, Detroit, and Phoenix, respectively. Relative to population size, which remains fixed at present-year levels for the future warming scenarios, the rate of heat mortality in Phoenix from a concurrent heat wave and blackout event is projected to exceed 1% of the total modeled population in mid-century and approach 2% of the population by late century.

The estimated number of ED visits resulting from a 5 day heat wave substantially increases in response to simulated blackout conditions. Based on health surveillance data recording daily emergency department visits for heat-related conditions, exposure-response functions have been derived to associate daily ED visits with temperature change in two of our three study cities: Atlanta and Phoenix.^{17,27} Employing the same analog temperature approach used to estimate heat-related mortality, we estimate the number of ED visits in response to our six scenarios in Figure 4. Under current conditions, a citywide blackout increases the rate of heat-

related ED visits (per 100,000 population) in Atlanta from 18 (total = 76) to almost 3,000 (approximate total = 12,540) over the 5 day event, representing approx. 3% of the population. In Phoenix, the estimated rate of heat-related ED visits increases from 18 (total = 260) under the Power On scenario to more than 56,000 (approximate total = 816,570) visits under the Power Off scenario, representing more than 50% of the population.

Citywide urban heat management strategies reduce heat-related morbidity associated with a concurrent heat wave and blackout event in both cities. An expansion of street trees to 50% shading over roadways reduces the rate of ED visits by almost 70% in Atlanta and 8% in Phoenix. The conversion of all building roofs to cool materials reduces the rate of ED visits by 80% in Atlanta and 15% in Phoenix.

Accounting for more intense heat waves in future years, a concurrent heat wave and blackout event by mid-century increases the ED visit rate in Atlanta approx. 7-fold to more than 20,000 per 100,000 population. The ED visit rate in Phoenix increases by 7% over the base year Power Off scenario. By late century, the fraction of the urban population requiring emergency medical services from the simulated compound climate and infrastructure failure event is estimated as more than 40% in Atlanta and 68% in Phoenix.

DISCUSSION

We estimate a magnitude of health risks associated with a compound climate and infrastructure failure event across the three large U.S. cities that is well in excess of prior work focused on extreme heat events in urbanized areas.^{31,32} Our measure of IET, accounting for individual-level heat exposures responsive to localized outdoor and indoor climates, provides a more accurate metric of individual heat exposure than the use of single, stationary outdoor temperature sensors at regional weather stations. While the substitution of IET in exposure-response functions does not result in elevated estimates of heat wave mortality or morbidity relative to prior studies when electrical grids are assumed to be operational,^{33,34} the simulated loss of mechanical AC for residents with access to AC systems greatly elevates indoor heat exposures, serving in turn to elevate the analog temperatures used herein to estimate health impacts. Simulated blackout conditions for a historical 5 day heat wave more than doubled the rate of heat mortality in Atlanta and Detroit and increased the rate of heat mortality in Phoenix—where average heat wave temperatures exceed 37 °C—to almost 1% of the total urban population.

The more pronounced risk of heat mortality and morbidity in Phoenix relative to Atlanta and Detroit can be attributed both to the higher temperatures experienced during an extreme heat wave event and a disproportionate impact of blackout conditions for cities with a high AC prevalence. Ambient heat wave temperatures in Phoenix reach a maximum intensity 9–10 °C greater than daily high temperatures in Atlanta or Detroit, while minimum temperatures only fall to 32 °C, sustaining high heat exposures over a full 24 h period for successive days. In addition to more intense heat wave conditions for residents of Phoenix, the loss of electrical power produces a disproportionately greater shift in individual heat exposures than estimated for residents of Atlanta or Detroit. Reported in Table 3, the shift in IET resulting from a loss of electrical power during heat wave conditions is 2.2 and 1.6 °C in Atlanta and Detroit, respectively, and more than 6 °C in Phoenix. Phoenix is not only hotter than Atlanta or Detroit, the shift in individual heat exposures in response to a loss of AC is about 3-fold greater, on average, than for residents of Atlanta or Detroit—an outcome that results from both high heat wave temperatures and an AC prevalence rate that approaches 100%. Protective of health during heat wave periods with an operational electrical grid, high AC prevalence may have the unintended effect of amplifying heat vulnerability during grid failure events.

While none of the cities included in the study has experienced a concurrent heat wave and blackout event of the intensity and duration modeled herein, recent surveillance data focused on the unhoused population in Phoenix find a heat-mortality rate comparable to that estimated to result from a citywide compound climate and infrastructure failure event. The Maricopa County Public Health Agency, which serves more than 90% of the Phoenix metropolitan population, reported 130 heat-related deaths among an unhoused population of approx. 8200 during 2021 or a heat-mortality rate of 1580 per 100,000.^{35,36} Representing approx. 1.6% of the estimated total unhoused population, this estimate of the heat-mortality rate among a population lacking regular access to shelter or mechanical air conditioning falls within the same order of magnitude of what we estimate to result from a concurrent heat wave and blackout event for the full Phoenix

population (~1%). An important limitation of this reference dataset for the Phoenix population, however, is the surveillance period, which is reflective of a full warm season as opposed to a single, intense heat wave event. In addition, differences in the baseline health and acclimatization to extreme heat between these two populations may yield different outcomes.

Our estimates do not account for individuals' behavioral adaptations or the actions of first responders during such a severe heat crisis. In reality, if a blackout event was regionally localized, many individuals would be able to leave their homes and travel to cooler locations. We also do not account for potential governmental responses to a concurrent heat wave and blackout, such as evacuation of the most vulnerable to heat illness or the deployment of mobile power generators for cooling centers. Other important sources of uncertainty in our analysis include (1) the degree to which measures of relative risk based on outdoor temperatures are reflective of indoor heat exposures, (2) uncertainties in the precision of the ambient and indoor temperature models used for the study, (3) uncertainties in behaviors and locations of individuals throughout the day and hence their daily IETs, and (4) uncertainties in the exposure-response functions in the applied epidemiology studies (including the changing nature of population susceptibility with a period of prolonged heat exposure).

These limiting assumptions notwithstanding our results suggest that the extent of heat morbidity in Atlanta and Phoenix resulting from a concurrent heat wave and blackout event carries the potential to overwhelm regional emergency medical systems. With almost three percent of the urban population in Atlanta estimated to require emergency medical care and more than half of the Phoenix population, the capacity of regional emergency departments to effectively treat heat illness would be exceeded in both cities (Atlanta has less than 2000 emergency department beds;³⁷ Phoenix has less than 3000 emergency department beds³⁸). Importantly, the exposure-response functions used in this study reflect heat morbidity rates during historical surveillance periods in which regional electrical grids are fully or largely operational. The inability of regional emergency medical systems to treat widespread heat illness during periods of electrical system inoperability due to the large number of residents requiring medical care may indicate that a higher rate of heat mortality than estimated by our approach would result.

The substantial magnitude of heat risk in Phoenix, with more than 50% of the population at risk of heat illness from blackout conditions during a heat wave of historical intensity, suggests the imperative for a high level of electrical grid resilience and back-up power generation, particularly for critical facilities such as hospitals. Burillo et al.³⁹ found the potential for cascading electrical grid failures across Arizona to increase 30-fold in response to a 1 °C rise in average annual temperatures, suggesting a growing potential for compound events over time. Most critical is investments in back-up power generation at regional cooling centers to ensure critical public health protections during blackout conditions and an expansion in the number of cooling centers to accommodate larger populations during compound climate and infrastructure events. We estimate that the total number of cooling centers in each of the three study cities would likely accommodate less than 1–2% of the urban population in the event of a concurrent heat wave and blackout event.⁸ As the frequency and intensity of extreme heat events continues to rise, all cities

should be working to enhance electrical grid resilience during heat wave conditions.

The extremity of the estimated risk for heat-related mortality in Phoenix and of heat morbidity in both Atlanta and Phoenix, highlight the need for more comprehensive emergency response preparations by local, state, and federal officials. Such plans should address emergency cooling needs, the provision of drinking water should water treatment and delivery systems fail, and the potential need for evacuation and temporary housing for residents lacking access to personal vehicles. At present, state-level hazard mitigation plans in Arizona, Georgia, and Michigan do not identify an electrical grid failure during an extreme heat event as a defined class of hazard. The Arizona Department of Health Services identifies an electrical grid failure event during the summer months as requiring the highest level of governmental emergency response but offers limited details on what responses would be deployed.⁴⁰ In light of the rising frequency of electrical grid failure events, in concert with a rising incidence of extreme weather events nationwide, compound climate and infrastructure failure events should be directly addressed through governmental hazard mitigation and emergency response planning.

Conventional urban heat management strategies, including an enhancement of citywide street tree canopy and the use of high albedo roofing materials, potentially carry significant benefits for lessening heat risk during concurrent heat wave and blackout events. Across the three study cities, street trees lessened heat-related mortality by an average of 20%, while cool roofing could lessen heat-related mortality by an average of 37%. Both strategies also were highly effective at reducing estimated heat morbidity in Atlanta and Phoenix, with the modeled increase in street trees and cool roofing associated with an average reduction in ED visits of 39 and 48%, respectively. While we did not simulate the effects of both enhanced street tree area and cool roofing simultaneously, other studies have found the combination of these strategies to yield a marginally lower cooling effect than the sum of these two strategies modeled independently.^{41,42} Importantly, our approach estimates benefits of cool roofing for both reduced ambient and building-interior temperatures, while street trees are not assumed to shade buildings in our modeling, and thus, no building-interior reductions in temperature from direct tree shading were considered. Prior work accounting directly for the benefits of tree shading for indoor climates finds significant cooling benefits that are not reflected in our results.⁴³ Moreover, our estimate of reduced mortality from expanded tree canopy does not account for direct radiative effects on (i.e., direct shading of) pedestrians and thus may underestimate the full benefits of this strategy.

We assume an extent of tree canopy shading over roadways that exceeds present canopy extents in each of the study cities but likely would be achievable over time for all but the largest roadways. While citywide data on street tree coverage over roadways are not available for Atlanta, Detroit, or Phoenix, data for Chicago, as an example, find streets to be shaded by an average of 35% when measured at the Census block group level, with 14% of all block groups found presently to have tree shading of roadways at 50% or greater,⁴⁴ illustrating the potential to achieve this level of canopy cover over streets in a highly urbanized environment. Likewise, we set roof albedo values at levels presently achievable with commercially available products for both commercial and residential roofs.

We believe the heat management targets set in this study are ambitious but physically attainable over time in each of the study cities, albeit with differing levels of investment needed in supporting infrastructure and more pronounced constraints on water resources for irrigation in Phoenix.

A rising potential for compound climate and infrastructure failure events in large cities of the U.S. highlights a pronounced vulnerability of urban populations confronting more extreme heat in all regions of the country.⁴⁵ In this study, we find the health impact of a multiday electrical grid failure event during heat wave conditions, and in the absence of cooling interventions, to be substantially greater than the estimated levels of heat mortality and morbidity associated with a heat wave alone. We further find this amplifying effect of infrastructure failure on health outcomes to rise rapidly by middle to late century, as heat wave intensities exceed historical levels. Widespread physical changes to the built environment of cities, enhancing evapotranspiration, shading, and solar reflection, carry the potential to measurably reduce estimated levels of heat illness and death.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at <https://pubs.acs.org/doi/10.1021/acs.est.2c09588>.

Distribution of IET by city for the Power On, Power Off, Cool Roof, and Street Tree scenarios in the present time period (Figure S1) and extrapolated RR curves based on ref 18 for Atlanta, Detroit, and Phoenix (Figure S2) (PDF)

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Notes

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Energy Burden and Economic Poverty in the US

Do Energy Burdens Contribute to Economic Poverty in the United States? A Panel Analysis

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For many households, energy consumption represents a non-discretionary portion of their budget and directly relates to quality of life. As researchers continue to study the environmental impacts of energy behavior, it is important to explore how energy consumption relates to socio-economic wellbeing. This paper examines the economic impacts of being energy-burdened in the United States, defined as spending at least 10% of household income on heating and electricity services; energy burdens are partially, but not entirely, driven by income, since energy needs and costs can vary substantially due to housing characteristics, utility rates, and other factors. Using panel data of US household income and energy expenditures during 1999–2017, this analysis demonstrates that energy-burdened households were at about 150%–200% greater risk of transitioning into or extending the duration of economic poverty over a two-year timeframe relative to non-burdened households. This analysis indicates that dedicating inordinate amounts of income to energy services can threaten a household's economic well-being over time, possibly by preventing a household from engaging in other economic activities or compounding existing economic hardship. These results emphasize the importance of energy assistance and energy efficiency for low-income households, drawing attention to how structures of energy consumption, the welfare state, and social stratification intertwine.

Introduction

Energy consumption in the United States is often viewed in terms of excess. But energy scarcity—that is, access to affordable energy—will become increasingly relevant if policies internalizing the environmental costs of energy production lead to increased prices and leave some households vulnerable to energy burden

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(Price, Brazier, and Wang 2012). Non-discretionary energy consumption can impose financial hardships for many US households despite rationing and efficient behavior intended to minimize spending (Hernández and Bird 2010; Evens 2015). Rather than behavioral overconsumption, the financial burdens from energy use for these households primarily result from inefficient housing and insufficient capital to invest in improvements (Boardman 2012). Although scholarly attention to energy burdens in the industrial and post-industrial world is growing, fewer studies have examined energy burdens in the United States. Given the relatively weak US welfare state, where benefits often flow toward more affluent households (subsidizing for energy efficient appliances, e.g.), we should expect rising energy costs to push vulnerable populations to remain or fall into economic insecurity.

In this paper, we examine household energy costs in the United States, focusing on households that spend 10% or more of their total income on heating and electricity. Using longitudinal data, this analysis investigates the relationship between household energy burden and vulnerability to future economic poverty. While households vulnerable to economic poverty are by definition vulnerable to energy burdens, we assume that since energy budgets are at least partly beyond the agency of individual households, they present barriers to activities that help households avoid or transition out of economic poverty. In other words, by demonstrating an association between energy burden and future economic poverty, this analysis suggests that energy burdens serve as an obstacle to preventing or transitioning out of poverty. We conclude with future lines of research considering these results, making connections between energy burden, social stratification, and environmental social science.

Energy Burden and Poverty

Transitions into poverty and economic insecurity constitute a vast and important area of research in sociology and related disciplines. Without reviewing this scholarship in full, it is fair to state that researchers often focus—with good reason—on changes to earnings and employment status as the predominant predictors of poverty entry (Bane and Ellwood 1986; Ruggles and Williams 1987; Jenkins 2000; McKernan and Ratcliffe 2005; Brady, Finnigan, and Hübgen 2017). In addition to these major factors, researchers have examined “trigger events” that put households at greater risk of poverty entry or bankruptcy, such as family dissolution, injury, or ill health (DiPrete and McManus 2000; Smith 2004; Himmelstein et al. 2009; Maroto 2015; Tach and Eads 2015). Despite the rich body of work in this area, the complexity of unraveling the causal pathways to poverty entry leaves room for additional research connecting events to economic insecurity (Western et al. 2012).

Energy burdens may constitute a risk factor that has received less attention in the existing research. Research on energy insecurity lends insight into how this experience may lead to future poverty spells. Hernández (2016) provided a conceptual framework, outlining the economic components of energy insecurity

and the various burdens to which it exposes households. In addition to the health consequences of living in cold, dark, and damp conditions, which can lead to debt accumulation or lost wages, [Hernández \(2016\)](#) found that many energy insecure residents prioritize housing payments and food costs over utility bills when forced to choose (a point reinforced by [Finnigan and Meagher 2019](#)). The resulting utility debt can lead to an economic cycle of “playing catch up.” Such debt can limit the ability to secure new housing as arrears can prevent the transfer of utility services to new addresses, potentially locking households into structurally inefficient homes, and demanding resources that households could otherwise invest in avoiding or transitioning out of poverty (work-related capital, schooling, or training, etc.). Utility disconnection is also linked with increased risk of eviction ([Desmond 2016](#); [Finnigan and Meagher 2019](#)), food insecurity, telephone disconnection, unmet medical needs, and other forms of material hardship ([Heflin 2006](#)).

In the case of eviction, [Desmond’s \(2016\)](#) qualitative research in Milwaukee, Wisconsin finds that evictions spike in the summer and early fall when low-income households prioritize catching up on their utility bills to avoid disconnection before the winter shut-off moratorium begins, and evictions decline over the winter when households can stop paying their utility bill without risking a disconnection. Interviews conducted by [Hernández \(2016\)](#) of low-income families revealed utility bills cumulating to thousands of dollars, restricting discretionary income, and putting households into long-term debt. In their ethnographic research, [Harrison and Popke \(2011\)](#) shed light on the challenges of energy-burdened households deciding between paying utility bills and covering their medical and nutritional needs.

At a meso-level, the experience of energy burden can prevent families from moving out of low-resource neighborhoods and establishing social connections that facilitate economic opportunity. While social networks can provide private safety nets that help mitigate the consequences of triggering events ([Heflin, London, and Scott 2011](#)), a large majority of Americans experiencing missed utility payments report receiving no outside help; of those who do, about half receive support from friends and family ([Finnigan and Meagher 2019](#)). Researchers have linked inadequate access to affordable energy with household food insecurity ([Cook et al. 2008](#); [Bhattacharya et al. 2003](#)), health and child development risks ([Cook et al. 2008](#); [Hernández 2013](#); [Hernández 2016](#)), social network disruption ([Harrison and Popke 2011](#)), and mortality during heat waves ([Klinenberg 2002](#)).

The trade-off between paying energy bills and sacrificing basic needs is documented across several pieces of research. A US Energy Information Administration report indicated that about a third of households faced challenges in paying their energy bill in 2015, and about a fifth of households reduced or forwent basic necessities for at least a month to pay their energy bill ([U.S. EIA 2015](#)). A whitepaper produced for the Senate Committee on Energy and Natural Resources explored how energy costs can push families to poverty entry or cause food insecurity ([Murkowski and Scott 2014](#)). A statewide report in Colorado

found the inability to pay utility bills as one of the leading causes of homelessness behind job loss and family breakup (Center for Education Policy Analysis 2006). Utility shutoffs can exacerbate or cause illness (Hernández and Bird 2010), and landlords may use disconnection as grounds for eviction in some circumstances (Verclas and Hsieh 2018).

Eviction, food insecurity, and other material hardships often associated with energy burdens could initiate or prolong a cycle of poverty. The inability to access affordable energy services can prevent participation in certain economic activities and serve as a barrier to upward mobility (Sovacool, Sidortsov, and Jones 2014). We suggest that energy burdens may be one of several triggering events preceding poverty entry (Bane and Ellwood 1986; DiPrete and McManus 2000).

The concept of energy burden provides a structure for theoretical and empirical analysis of energy access and its implications for human welfare. We can conceptualize energy burden in terms of access to affordable, safe, and sufficient energy services or as a disproportionate (and non-discretionary) share of household resources dedicated to energy needs. A key part of this concept is that, to a certain extent, energy consumption is non-discretionary. Just as some basic amount of food consumption is essential for human welfare, some basic amount of energy consumption is essential for maintaining well-being, such as for heating and cooling, cooking, and lighting. Households are constrained in how much energy use can be reduced without compromising health and well-being, while energy efficiency improvements can both reduce energy needs and improve health (Wilson et al. 2016; Büchs et al. 2018). Various researchers have defined burdens in terms of actual expenditures using 6%, 10%, or 20% thresholds, estimated energy costs associated with heating a home to a particular temperature, or combinations of high costs with low incomes (Boardman 1991; APPRISE 2005; Moore 2012). While energy burdens are clearly linked with income and thus economic poverty, the two are not perfectly aligned. Moderate income households may be susceptible to energy burdens just as households living in economic poverty are not necessarily dedicating a large share of their income to energy needs. Furthermore, focusing on expenditures fails to capture energy rationing among lower income households; energy expenditures are thus distinct from “affordable warmth” discussed in the fuel poverty literature (Boardman 2010), which takes into account necessary costs to reach a particular temperature.

The amount of total income resources dedicated to energy varies across class boundaries, with middle- and upper-income households typically spending 5% or less while poor households may spend 10%, 20%, or even greater proportions of their income on energy services (Evans 2015; Drehoobl and Ross 2016). Income dedicated to energy services limits the resources available for other actions, so fluctuating energy costs can greatly affect resources available to satisfy other basic needs, including food (Bhattacharya et al. 2003). At the same time, energy consumption does not increase in a simple linear fashion with income, and some low-income households use more energy per square foot of housing space due to less efficient appliances and temperature control systems (Evans 2015, using electricity data for Chicago-area households).

Qualitative research in the United States indicates that low-income households experiencing high energy burdens are not profligate in their behavior, displaying high levels of rationing energy consumption in everyday life. Some low-income households restrict energy use to the point where they are unable to maintain World Health Organization recommended minimum home temperatures (Hernández and Bird 2010; Middlemiss and Gillard 2015). The relationship between energy burden and poverty is not simply a matter of income, but also a function of home characteristics and related factors that influence energy needs (the Methodology section provides further details on the correlation between energy burdens and poverty). Research in the United Kingdom has identified constraints on controlling energy costs driven by: housing quality; tenancy relations and the “split incentive” problem (see below for details); utility rates (which vary substantially across the United States) as well as fees and debt; and non-negotiable energy needs of household members (Middlemiss and Gillard 2015). Poverty clearly increases the likelihood of energy burden simply due to low income, but may also exacerbate energy burden on the cost side through these factors. Recent research has found that energy use intensity, or the consumption of heating or cooling energy per square foot of living space, is higher in lower income neighborhoods in Detroit, Michigan (Bednar, Reames, and Keoleian 2017) and Kansas City, Missouri (Reames 2016). On the other hand, experiencing energy burden may place a household at greater risk of poverty, since reduced discretionary funds can limit a household’s ability to invest in education, job training or economic capital, or make contributions to savings. Energy-burdened households may become vulnerable to utility debt, further adding to these constraints.

Parallel research on housing affordability has found that families facing housing cost burdens (commonly defined as costs greater than 30% of household income) face a variety of challenges: increased odds of poor self-rated health and various medical conditions (Pollack, Griffin, and Lynch 2010); less ability to invest in child education (Newman and Holupka 2014); and less money set aside in savings (Mendenhall, Kramer, and Akresh 2014). Like housing costs, energy costs are at least partially fixed and essential to household wellbeing. Although energy costs are usually substantially smaller than direct housing costs (i.e., rent, mortgage payments), higher energy costs nonetheless reduce discretionary funds and likely impact low-income families in similar ways to housing cost burdens. Additionally, housing is a productive asset that can support investments in social or human capital, or generate income (Moser 1998). Applying the asset vulnerability framework, energy inefficient housing may less effectively guard against poverty spells.

In general, housing is a critical factor on both the energy and poverty sides and has a significant impact on household energy needs. Tenants in rental housing face additional hurdles to managing their energy costs, since they are typically unable to invest in energy efficiency upgrades for their homes. This situation compounds behavioral and other barriers to energy efficiency that poor households face, since most households within 150% of the federal poverty level reside in rental housing and about 75% of renters pay their own utility bills (U.S.

EIA 2015). From an ownership standpoint, landlords have minimal incentive to improve the energy efficiency of the units they oversee. This falls under a “split incentive problem,” where landlords do not accrue direct benefits from their investments in energy efficiency, while occupants responsible for paying energy bills do not have the opportunity to make structural changes to their dwelling (Gillingham, Newell, and Palmer 2009; Hernández and Bird 2010). Thus, the rental homes that many poor households occupy are often less efficient and subject to higher energy costs for heating and cooling, which may contribute to higher levels of energy rationing and less healthy home temperatures (Gillingham, Harding, and Rapson 2012; Middlemiss and Gillard 2015).

Energy Assistance and the Welfare State

The US has had a federally coordinated energy assistance policy since 1981, when the Low Income Home Energy Assistance Program (LIHEAP) was established to assist low-income households in meeting their home energy needs. The most common LIHEAP qualification threshold for household income is 150% of federal poverty guidelines, although many states use other thresholds. LIHEAP typically covers only a small portion of total energy bills and has historically reached only a fraction of eligible households, between 10% and 20% (APPRISE 2005; Kaiser and Pulsipher 2006). There are various other federal, state, local, and utility programs that encourage energy efficiency and renewable energy or provide assistance to low-income households. However, assistance programs generally do not have sufficient funds to serve all applicants, while energy efficiency programs often require partial payments from customers that present a barrier to low-income households (Evans 2015).

Since Lutzenhiser and Hackett’s (1993) call for sociologists to connect environmental problems and energy with stratification and social welfare, relatively few scholars have answered. Welfare state research includes diverse contributions on tax systems (Prasad 2011, 2012), health care reform (Hacker 2004), and other topics, but little consideration to date regarding energy burdens. A comprehensive review of the welfare state literature lies beyond the scope of this paper, but it is worth highlighting the theoretical framework developed by Weir, Orloff, and Skocpol (1988), who explain the relatively weak US welfare state in terms of institutional structure: unlike the centralized bureaucratic states of Western Europe and their comparatively generous welfare expenditures, regional patronage networks and piecemeal bureaucratic-professional reforms characterize US history, preventing a robust welfare state from developing. Consistent with this, Hacker (2002) and Mettler (2011) both emphasize the extent to which US policy operates via indirect benefits (a tax break rather than direct provision, for example), which can easily fail to reach vulnerable populations in favor of the relatively affluent. These perspectives are also consistent with the various energy efficiency and clean energy tax credits and deductions, and the fact that these benefits primarily go to wealthy households (Borenstein and Davis 2016). Given such trends, we should expect that many households negatively impacted

by energy burdens find insufficient welfare state resources available to help, and the patchwork of federal, state, local, and utility programs are unlikely to fill the gap (Evans 2015).

We can logically assume that at the level of households, transitioning into economic poverty and the lower income it entails will increase the likelihood of experiencing energy burden. If the transition into economic poverty is preceded by a loss of household income, then—following the logic of Engel’s law of food elasticity (Engel 1857)—we can assume that the share of income dedicated to energy consumption will rise above operational definitions of energy burden. Yet the reverse direction has not been investigated, leading to the key research question here: does energy burden increase the likelihood of extending or entering economic poverty? In this analysis, we test the hypothesis that it does. Given the relatively non-discretionary nature of energy consumption, the cycles of debt energy burdens can initiate, and the social and health consequences of energy insecurity, we expect to find connections between energy burdens and future economic poverty status.

Data

Data for this project come from the Panel Study of Income Dynamics (PSID), a longitudinal survey of households that began in 1968 with an initial sample of nearly 5,000 US families. Data for this analysis come from household energy consumption gathered between 1999 and 2017 (waves 31–40).

Three measures of poverty serve as dependent variables, using income thresholds for defining poverty according to whether a household lives within 100%, 150%, or 200% of per capita household poverty guidelines contained in the PSID. These thresholds are based on detailed poverty tables from the Census Bureau that account for family size and number of related children.^{1,2} (In 2017, families of four with two children and a total income of \$24,944 or less fell within 100% of poverty guidelines.) Most households living within 150% of the poverty level qualify for LIHEAP subsidies, although different states use different thresholds.³ Additionally, it is common practice when using PSID data in particular to operationalize poverty at greater than 100% of federal guidelines (Cellini, McKernan, and Ratcliffe 2008) or when studying US poverty in general to analyze it according to multiple indicators (Ruggles 1992).

Respondents were asked how much they spend on heating or gas fuel and electricity per month.⁴ Although energy costs are expected to fluctuate across seasons, the PSID survey does not capture this seasonality but instead asks about typical monthly costs.⁵ To test the effect of energy burden, this amount was calculated as a share of total household monthly income from the previous year. A dummy variable was created with 1 = households that spend at least 10% of their monthly income on heat and electricity combined, conceptualized as households that face energy burdens. Respondents whose utility bills are included in their rent were dropped from analysis (accounting for about a fifth of all renters). This metric uses energy expenditures, and does not account for

the level of energy use necessary for a household to maintain healthy home temperatures, such as the “low income/high cost” measurement modeled by Hills (2011). The PSID data likely suffer from a “rounding strategy” used by respondents to self-report consumption expenditures (Pudney 2008), although the binary measure of energy burden should minimize this concern. Additionally, the PSID does not instruct respondents in how to handle utility subsidies when estimating monthly expenditures. Other independent variables are included to control for common predictors of poverty status. Since loss of income is an obvious potential cause for entering economic poverty, a dummy variable was created where 1 = a loss of at least 10% of household income from the previous wave. Ill health status was measured according to whether household heads assessed their health as fair or poor, with “good health” (those self-assessing as excellent, very good, or good) as the reference category. Both concurrent and lagged ill health were analyzed to control for the impacts of household heads’ ill health on economic wellbeing over time.

Several dummy variables were created to account for social structural location. These include whether household heads are female (which is time-varying in cases where female respondents become household heads for the first time), young (under 30), senior (65 or older), college graduates, and own their home. Dummy variables were also created for the type of health insurance a respondent had: private health insurance, other health insurance (provided for military veterans, e.g.), Medicare and/or Medi-Gap, or Medicaid, with uninsured as the reference category. Since economic poverty is measured on a per capita basis, new additions to the family unit could qualify a household as living in poverty even if their income remains stable. To account for this, a dummy variable was created, where 1 = households that reported new family members since the previous wave. Marital status is also controlled for, with concurrent dummy variables accounting for whether the household head is married, divorced, separated, or widowed, with single as the reference category. Lagged variables for marital status are not included because of likely collinearity with female head of household: since the PSID defined the head of household as male for all opposite-sex married or long-term cohabitating couples across all but the most recent wave included in this analysis, a household that transitions from a male head in a previous wave to female head concurrently would also experience a related change in marital status. Table 1 shows descriptive statistics of variables used in this analysis.

Methodology

A challenge of this research area is the role of income: it determines whether a household falls below the poverty thresholds, and by definition, energy burden is a function of income. Income is therefore part of the outcome (i.e., poverty), and included among the predictors as a component of energy burden. To address this mechanical correlation, we restrict inclusion of energy burden to its lagged state (two years prior), so that income is not used to calculate both concurrent poverty

Table 1. Descriptive statistics

Variable	Proportion (200% poverty rate _{t-1} = 1)	Proportion (200% poverty rate _{t-1} = 0)
Energy-burdened _{t-1}	0.46	0.09
10% income loss	0.23	0.45
Ill health	0.23	0.14
Private Insurance	0.24	0.44
Other Insurance	0.03	0.03
Medicaid	0.20	0.06
Medicare	0.04	0.05
New family member	0.19	0.18
Married	0.53	0.68
Divorced	0.14	0.11
Separated	0.07	0.05
Widowed	0.05	0.04
Homeowner	0.49	0.68
Female HH	0.39	0.23
Young HH	0.19	0.17
Senior HH	0.07	0.08
College grad	0.11	0.26

status and state of energy burden. When inspecting the relationship between lagged energy burden and corresponding poverty status after each model, all correlations were below 0.11.

Furthermore, by themselves, these poverty thresholds explain only a small proportion of the variation in energy burdens: we ran a series of logistic regressions predicting energy burden from different levels of poverty, predicting energy burden from total family income, and predicting each level of poverty from energy burden, resulting in a pseudo r^2 between 0.2 and 0.3. In other words, we cannot characterize the relationship between poverty and energy burden as a simple mechanical or spurious correlation due to low income. While our measure of energy burden is operationally tied to income, as is poverty, these data support our arguments that energy burden and poverty are neither conceptually nor empirically reducible to each other, and thus it is appropriate to use them in the same statistical model.⁶ This characterization is consistent with research on material hardship; although income loss is obviously and consistently related to medical, food, or housing hardship, such experiences are not reducible to income alone and can also be impacted by factors such as changes in health status, caring for family members with a disability, or drug use (Heflin and Butler 2012; Heflin 2016).

Given the binary dependent variables and panel structure of the PSID data, fixed effects logistic regression is utilized in this analysis (Allison 2009). Fixed

effects models offer the ability to measure within-unit change in the outcome over time, taking the following form:

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = \mu_t + \beta\mathbf{X}_{it} + \gamma\mathbf{Z}_i + \alpha_i, t = 1, 2, \dots, T$$

where p refers to the probability of household i at time t of displaying a positive outcome, μ is the intercept that may vary over time, $\mathbf{X}$ represents a vector of time-varying predictors, $\mathbf{Z}$ represents a vector of time-invariant predictors, and α represents the total effects of unobserved variables that remain constant over time. One consequence of restricting analysis to within-unit change is the inability to estimate time-constant variables such as race. Additionally, any unit that displays no variation in the outcome over the course of data collection is dropped from analysis. However, if researchers can partial out unobserved and time-constant heterogeneity while focusing on within-unit change in the outcome, they can make stronger claims to causal inference not available with cross-sectional survey analysis. While it is difficult to make direct claims about causality with observational data, by establishing a statistically significant relationship between dependent and independent variables, accounting for omitted variable bias, and establishing a temporal ordering of events, fixed effects panel designs offer more rigorous analysis than cross-sectional approaches (Finkel 1995; Frees 2004).

An additional challenge regards distinguishing between poverty entry and poverty extension. Prior and current states of poverty are correlated. To understand the relationship between energy burden and poverty status, it is important to know whether prior experience with energy burdens increases the likelihood of new entry into poverty, extends the duration of poverty, or both. With continuous outcomes, researchers often address this by estimating dynamic panel models that include lagged states of the dependent variable as predictors, using Arellano-Bond estimators to deal with resulting bias (Arellano and Bond 1991). However, there is less consensus regarding dynamic logit models. Instead of including lagged dependent variables as predictors, and taking inspiration from Stewart and Swaffield's (1999) study of low pay transitions in Britain, we restrict samples to whether a household was below a poverty threshold at the previous wave (models predicting the endurance of poverty), or above a poverty threshold at the previous wave (models predicting poverty entry). Sociologists working with repeated binary outcomes characterized by state dependence should consider adopting this stratifying approach, which is not commonly employed in the discipline.

Temporal ordering is established through the inclusion of lagged independent variables, including energy burden. For all models, unstandardized regression coefficients are presented in tables, while substantive discussion reports odds ratios. Finally, we ran sensitivity tests with several alternative model specifications:

- The addition of geographic controls, specifically fixed effects for state of residence.

- Operationalizing energy burden at 6% rather than 10% of household income, and as a continuous variable, to account for the depth of energy burden.
- The addition of housing type (single family homes, mobile homes, and multiunit structures).
- The addition of subsidies for rental housing and heat (as a continuous variable; about 5% of the sample received a government-funded heat subsidy, with an average annual payment of \$390).⁷
- A subset model: predicting 100% poverty within the population of families with income below 200% of the poverty threshold. This approach was used as an additional check regarding the role of income.

Results for these alternative model specifications were consistent with the results presented below. Stata code for the full analysis is available online.

Results

Table 2 presents results from fixed effects logistic regression estimating whether households fall within various poverty thresholds, restricted to households below the corresponding poverty level at the previous wave. These models represent whether a household endures a poverty status across concurrent waves. For context, most households in the positive outcome for Models 1 and 2 qualify for federal heating assistance.

The key variable of interest—whether a household was energy-burdened in the prior wave—is statistically significant in all models. Net of other factors, we see in Model 1 that energy-burdened households had about 175% greater odds of remaining in poverty two years later relative to their non-burdened peers. In Model 2 among households previously within 150% of the poverty threshold and net of other factors, those with prior energy burdens were about twice as likely to endure this economic status compared with households without prior energy burdens. In Model 3, we again see the impact of prior energy burdens resulting in over 100% greater odds of enduring a status below 200% of the poverty threshold. As noted above, this energy burden metric does not account for rationing or the level of energy use needed to maintain healthy home temperatures. Given the energy rationing described in qualitative studies, if data were available to capture the higher cost of “necessary” energy use, we would likely see an even more deleterious impact on economic status.

Several household demographics historically associated with economic poverty are controlled in these models. Unsurprisingly, adding new family members increased the odds of staying in poverty. Women who became new household heads had about triple the odds compared with male household heads of staying within 100% of the poverty threshold.

Focusing on transitions into poverty, table 3 presents results from fixed effects logistic regression, restricted to households above the corresponding poverty level at the previous wave. Across all three models, lagged energy burden had

Table 2. Unstandardized coefficients (and robust standard errors) for time-varying predictors from fixed effects logistic regression predicting different levels of poverty among households below the corresponding poverty level at the previous survey wave. Models control for year (not displayed)

	<i>Model 1: 100%</i> <i>poverty rate_{t-1} = 1</i>		<i>Model 2: 150%</i> <i>poverty rate_{t-1} = 1</i>		<i>Model 3: 200%</i> <i>poverty rate_{t-1} = 1</i>	
	Coef.	Robust St. Err.	Coef.	Robust St. Err.	Coef.	Robust St. Err.
Energy-burdened _{t-1}	1.019***	0.090	0.674***	0.06	0.761***	0.048
10% income loss	3.286***	0.132	3.219***	0.099	3.139***	0.093
Ill health _{t-1}	0.210*	0.097	0.064	0.065	0.035	0.057
Ill health	0.080	0.083	0.223***	0.064	0.039	0.054
Private Insurance _{t-1}	-0.593***	0.175	-0.232*	0.099	0.108	0.076
Private Insurance	-0.682***	0.157	-0.338***	0.086	-0.431***	0.068
Other Insurance _{t-1}	1.148***	0.218	0.581***	0.139	0.516***	0.129
Other Insurance	0.189	0.200	0.100	0.15	0.202	0.133
Medicaid _{t-1}	0.247*	0.106	0.108	0.076	0.466***	0.07
Medicaid	0.487***	0.100	0.692***	0.074	0.686***	0.071
Medicare _{t-1}	0.412	0.220	0.366*	0.158	0.328*	0.15
Medicare	0.198	0.220	0.576***	0.155	0.373**	0.137
New family member	0.194*	0.092	0.045	0.059	0.195***	0.05
Married	0.192	0.198	0.907***	0.148	0.266*	0.115
Divorced	-0.716***	0.201	-0.716***	0.14	-0.400***	0.107
Separated	-0.079	0.180	-0.072	0.157	-0.282*	0.127
Widowed	-0.942***	0.266	-0.571**	0.203	-0.201	0.177
Homeowner _{t-1}	-0.485***	0.122	-0.100	0.086	-0.310***	0.068
Homeowner	-0.269*	0.111	-0.233**	0.079	-0.443***	0.067
Female HH	1.286***	0.205	1.842***	0.153	1.081***	0.11
Young HH	-0.326**	0.101	-0.286***	0.074	-0.207**	0.065
Senior HH	-0.060	0.279	0.159	0.168	0.813***	0.145
College grad	-1.034***	0.254	-1.073***	0.134	-0.772***	0.112
N	7,971		13,982		19,589	

* p < 0.05, ** P < 0.01, *** P < 0.001

Table 3. Unstandardized coefficients (and robust standard errors) for time-varying predictors from fixed effects logistic regression predicting different levels of poverty among households above the corresponding poverty level at the previous survey wave. Models control for year (not displayed)

	<i>Model 4: 100% poverty rate_{t-1} = 0</i>		<i>Model 5: 150% poverty rate_{t-1} = 0</i>		<i>Model 6: 200% poverty rate_{t-1} = 0</i>	
	Coef.	Robust St. Err.	Coef.	Robust St. Err.	Coef.	Robust St. Err.
Energy-burdened _{t-1}	1.109***	0.068	0.921***	0.072	0.453***	0.076
10% income loss	4.050***	0.087	3.598***	0.067	3.091***	0.054
Ill health _{t-1}	0.243***	0.07	0.028	0.066	0.144*	0.069
Ill health	0.157*	0.066	0.248***	0.064	0.184**	0.064
Private Insurance _{t-1}	-0.072	0.085	0.015	0.076	0.093	0.072
Private Insurance	-0.546***	0.083	-0.448***	0.071	-0.329***	0.064
Other Insurance _{t-1}	0.103	0.186	0.440**	0.162	0.501**	0.152
Other Insurance	0.540***	0.146	0.459**	0.145	0.636***	0.140
Medicaid _{t-1}	0.098	0.093	0.619***	0.098	0.744***	0.113
Medicaid	0.642***	0.084	0.576***	0.083	0.814***	0.092
Medicare _{t-1}	0.060	0.171	0.316*	0.155	0.182	0.133
Medicare	0.105	0.157	0.194	0.139	0.131	0.123
New family member	0.499***	0.067	0.702***	0.060	0.714***	0.056
Married	-0.743***	0.112	-0.596***	0.095	-0.657***	0.098
Divorced	-0.407***	0.117	-0.692***	0.113	-0.345**	0.117
Separated	-0.729***	0.125	-0.477***	0.122	-0.043	0.138
Widowed	-0.369*	0.187	-0.032	0.170	0.038	0.180
Homeowner _{t-1}	-0.152*	0.071	-0.205**	0.067	-0.055	0.067
Homeowner	-0.702***	0.072	-0.903***	0.067	-0.859***	0.061
Female HH	0.319**	0.101	0.695***	0.098	0.272**	0.094
Young HH	0.379***	0.074	0.401***	0.071	0.440***	0.069
Senior HH	-0.039	0.156	0.044	0.136	0.071	0.126
College grad	-0.722***	0.111	-0.659***	0.095	-0.499***	0.086
N	23,531		28,517		30,406	

* p < 0.05, ** P < 0.01, *** P < 0.001

a statistically significant relationship to concurrent poverty status. Relative to non-burdened households, those with prior energy burdens had about double the odds of transitioning into poverty (Model 4), 150% greater odds of transitioning within 150% of the poverty threshold (Model 5), and about 60% greater odds of transitioning within 200% of the poverty threshold (Model 6). The impact of prior energy burdens on concurrent poverty status again accounts for whether a household experienced a substantial loss in income, which is obviously the single largest driver of the outcome across all models.

As with Models 1–3, Models 4–6 control for a variety of other variables commonly associated with transitions into economic poverty. Both married and divorced heads of household were less likely to transition into poverty relative to single household heads. Likewise, owning a home or graduating from college were positive predictors of economic wellbeing.

Although a full discussion of the role of health is beyond the scope of this paper, it is worthy to note the impact of health on economic wellbeing. In Model 4, for example, household heads rating their subjective health as fair or poor had about 20% greater odds of entering poverty two years later, compared to their counterparts rating their health as good, very good, or excellent. Concurrently having private health insurance predicts economic wellbeing. This is consistent with other research suggesting that access to health insurance through the Affordable Care Act marketplace may lower home mortgage delinquency rates (Gallagher et al. 2017), and is aligned with research linking maternal health with entrance into material hardship in the forms of food insufficiency, utility disconnections, unmet medical needs, and housing problems (Heflin 2013).

Discussion

These results clearly point to the economic disadvantage faced by energy-burdened households. As policymakers and activists continue to address energy consumption as part of climate change mitigation, it is important to recognize how increased energy prices could affect economically vulnerable households. Impacts from increased energy costs can be immediate, for instance if a household reduces expenditure on other necessities in order to heat the home (Bhattacharya et al. 2003), or when a household falls behind on their utility bills and consequently harms their credit rating (see Fourcade and Healy 2013 on the stratifying effect of credit ratings in the United States). Activists and policymakers should keep in mind that too many households lack a proper safety net to secure them from policies that increase energy costs. For researchers and theorists, this analysis highlights how energy burdens may act as triggering events for poverty entry and draws attention to the inadequacy of welfare state programs addressing this. We hope this analysis points to how energy consumption, the welfare state, and social stratification are intertwined.

Environmental activists, program implementers, and policymakers should keep these energy equity issues in mind when confronting potential

transitions to cleaner energy. For example, programs offering energy efficiency or clean energy services for low-income households can simultaneously work toward economic equity (by ensuring access to affordable energy) and environmental mitigation (by ensuring cleaner and/or more efficient energy consumption), social concerns historically brought up by [Lutzenhiser and Hackett \(1993\)](#). Ideally, renewable energy and energy efficiency programs would be accessible to low-income households, with funding assistance if necessary, since utility hardships are linked with other forms of hardship and assistance may reduce risks in other areas ([Finnigan and Meagher 2019](#)). In reality, activists and policymakers need to consider energy burdens in three policy areas: energy assistance, energy efficiency programs, and clean or renewable energy programs.

These results demonstrate that the benefits of energy efficiency and weatherization could extend beyond energy use to include reduced risk of economic poverty. For example, home insulation can last 80 years or more, effectively serving the duration of residency for a given household. Direct energy assistance may offer similar benefits in the short term, although future research should confirm that direct and weatherization assistance can mitigate the results found in this analysis. In terms of program design, high-quality and well-funded low-income energy programs may help reduce the risk of economic poverty while supporting environmental, climate, and other goals. We suspect, however, that current funding levels for LIHEAP and weatherization programs insufficiently mitigate inadequate energy access, at least at the federal level. Historically, LIHEAP and federal weatherization assistance funding has served only a fraction of eligible households ([Higgins and Lutzenhiser 1995](#)), although it can be a critical form of assistance for those who receive it ([Murray and Mills 2014](#)), and federal weatherization assistance programs have reduced energy bills by 12% on average ([U.S. DOE 2015](#)). Nonetheless, policy or activist efforts to address climate change mitigation could consider energy consumption as a site of intersection that simultaneously addresses social and environmental concerns ([Hernández 2015](#)).

To maximize the benefits of energy efficiency programs, these programs must be accessible to low-income households. This potentially requires greater funding for direct assistance or to address building health and safety issues that must be fixed before a retrofit can safely proceed ([Scheu et al. 2018](#)). Furthermore, to the extent that low-income households engage in energy rationing, low-income efficiency programs may see smaller energy savings but greater benefits in terms of healthy home temperatures and other non-energy benefits. For energy efficiency programs to be accessible to renters, these programs need to target multifamily building owners. Landlords remain key to the reform of energy consumption. [Bird and Hernández \(2012\)](#) suggest incentivizing landlords to take on energy efficiency upgrades for their units by covering the cost of loan financing in exchange for committing their property to low-income renting for the period of the loan. Future research could help to encourage multifamily energy efficiency by evaluating the benefits for landlords who do not pay utility

bills, for instance more comfortable housing units that reduce tenant turnover and increase net operating income for the building (Philbrick, Scheu, and Brand 2016). Energy efficiency programs targeting multifamily buildings can offer services to a significant share of low-income renters. For example, in Chicago, 59% of multifamily housing units are in low-cost, low-income neighborhoods, or are subsidized (Corso, Garascia, and Scheu 2017), and programs targeting these buildings may reduce energy burdens among low-income tenants. Research in the UK, however, indicates that income poverty spells typically last longer than fuel poverty (consistent with data used here), although rates of long-term fuel poverty exit vary across rural/urban settings, indicating that policies targeting housing stock may see inconsistent results (Roberts, Vera-Toscano, and Phimister 2015). Nonetheless, improving the efficiency of low-income housing will likely produce environmental benefits while potentially reducing the risk of energy burdens triggering poverty entry.

In addition to implications for activists, policymakers, and program implementers, these results also point to several fruitful directions for further research. We suspect the relationship between energy burden and economic poverty reflects multiple points of vulnerability and resource constraints relating to physical housing structure, neighborhood context, and consequences for social networks, physical health, or mental health. Energy burdens are understudied and need much more attention from social researchers to refine the mechanisms that connect this experience with poverty, and to understand the myriad coping strategies households employ. Comparative research could illuminate the effectiveness of policies and programs in mitigating these problems.

Other research areas could benefit from considering energy burdens as possible mechanisms, moderators, or complicating factors for other relationships. As one example, these results could hold implications for research on environmental risk perceptions and support for clean energy. Overall, lower-income individuals perceive greater long-term environmental risks than higher-income individuals (Trumbo et al. 2011; Lo 2014). Researchers could inquire how energy insecurity affects support for clean energy or climate change mitigation policy, particularly when those policies may result in slightly higher energy prices or inequitable impacts on consumers. Although renewable energy costs have fallen dramatically and are near parity with the cost of other fuels (Lazard 2016), carbon taxes or related instruments may nonetheless contribute to higher energy costs for some consumers, or the perception of higher costs. Additionally, tax credits and rebates for clean energy technologies can exacerbate inequity because upfront costs or credit requirements make them accessible primarily to the rich: 60% of US clean energy tax credits have gone to the top income quintile (Borenstein and Davis 2016). It is thus important to understand how perceptions of energy burdens or inequities affect support for social and environmental change. Energy justice could be crucial for working toward the goals held by mainstream environmentalists and clean energy movements.

Along this line of thought, several topics are proposed for future research to extend insights into energy burdens in the United States:

1. Does the experience of energy burden erode support for clean energy (assuming clean energy options are perceived as more expensive than conventional energy options)?
2. To what extent does energy consumption constitute a barrier to social mobility if basic needs exceed energy burden thresholds? How does energy burden compare to equivalent concepts of food and housing cost burden in terms of volatility and temporal patterns, and interrelationships? What are the relative impacts on poverty and social mobility of these and other independent causes of poverty?
3. In what ways does experiencing an energy burden contribute to poverty, and do the mechanisms vary in meaningful ways? What are the roles of housing (physical structure as well as affordability), health, financial constraints, cognitive capacity (Mani et al. 2013), utility rates and disconnection policies, and other factors?
4. What is the role of utility assistance, low-income weatherization assistance, LIHEAP, or other energy programs in moderating the relationship between energy burden and poverty? Do the programs that have the largest and longest-lasting impact on reducing energy use (e.g., weatherization) also have a large impact on reducing energy burden?

The first question brings a concern from social stratification (financial hardship) into the realm of environmental sociology and related social science by suggesting an analysis of support for clean energy development. The second question brings a concern from environmental sociology (energy consumption) into the realm of social stratification and material hardship and ties energy policy to broader poverty alleviation efforts, while the third question delves deeper into the processes that link energy and financial hardships. The fourth question addresses a potential moderating factor in that relationship and may have implications for program design and our theoretical understanding of the welfare state.

When analyzing energy consumption in the United States, sociologists typically focus on excessive use. But household energy scarcity could constitute an important topic for environmental sociology and social science more broadly, particularly in contexts where natural resource consumption to meet basic needs results in financial hardship. Sociological research in general would benefit from greater attention to energy burden and energy insecurity, in terms of financial hardships as well as variation in utility rates⁸, the impact of utility disconnection, the intersection of housing and energy, and other topics. This presents an opportunity for social scientists to engage in a larger discourse about social inequality that will be crucial to future conversations about energy and climate policy.

Notes

1. The models predicting income of 150% and 200% of poverty thresholds are included to address concerns in the literature that the 100% threshold is too low and reflects outdated modes of consumption. A full discussion of this issue is beyond the scope of this paper, but see [Ruggles \(1990, 1992\)](#) and [Blank \(2008\)](#) for examples. Additionally, since many states use 150% and 200% thresholds to determine qualification for energy assistance, it makes sense to extend analysis to these levels.
2. Although the supplemental poverty measure could account for differences in cost of living, it was not published by the US Census until 2011 and thus not available for many of the PSID waves analyzed here.
3. Another common threshold is 60% of the state median income, which is often higher than 150% of the federal poverty guideline, and some states extend the threshold to 200% of the poverty level. The LIHEAP Clearinghouse provides eligibility details for each state: <https://liheapch.acf.hhs.gov/snapshots.htm>.
4. Before 2011, this question asked about “gas or other types of heating fuel,” and was revised in 2011 to “gas or other types of fuel.” There are other small changes in PSID question wording over time, which we do not believe are likely to influence results. Models restricted to 1999–2009 produce results consistent with the models presented here.
5. There still may be a seasonal aspect to these data because respondents provide different estimates of typical monthly costs depending on when you ask them (e.g., average gas costs among respondents interviewed in March–May is \$164, versus \$157 in June–August). We ran basic one-way ANOVA tests for the influence of interview season, defining winter as December through February and summer as June through August, which is aligned with heating and cooling months for most of the United States. These models found a statistically significant effect of interview season on heating costs and electricity costs (both $p < .001$), and a marginally significant effect of interview season on combined heating and electricity costs ($p < .1$). We therefore ran additional sensitivity checks controlling for interview season, and the results are consistent with the models presented here.
6. We also explored the reverse relationship—different thresholds of economic poverty leading to energy burdens in a fixed effects logistic regression model. Results are available upon request, and indicate that lagged economic poverty is positively correlated with future energy burden status (controlling for factors described in the Data section).
7. Heating subsidies are not included in the main model due to potential double-counting (if respondents track subsidies as reduced expenditure, then they are incorporated into the energy burden metric), and a potential spurious correlation due to eligibility criteria. LIHEAP “crisis” assistance is only available to households at risk of disconnection (i.e., who are behind on their utility bills), and many states use higher income eligibility thresholds and/or provide larger subsidies for crisis assistance. These characteristics would

select for households at risk of poverty entry or extension. Historically, LIHEAP participation was strongly predicted by households receiving other forms of social welfare (SSI, e.g., Higgins and Lutzenhiser 1995).

8. State-level average residential prices for electricity in the contiguous United States in May 2018 ranged from 9.53 cents/kWh in Louisiana to 21.69 cents/kWh in Massachusetts (U.S. EIA 2018). Rates and rate structures also vary within states, for example, flat rates, time-of-use rates, inclining or declining block rates, flat customer charges versus volumetric charges, etc.

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ORIGINAL ARTICLE | LIFE EXPECTANCY

Marked Disparities in Life Expectancy by Education, Poverty Level, Occupation, and Housing Tenure in the United States, 1997-2014

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ABSTRACT

Objectives: Socioeconomic disparities in life expectancy in the United States (US) are marked and have widened over time. However, there is limited research using individual-level socioeconomic variables as such information is generally lacking or unreliable in vital records used for life table construction. Using longitudinal cohort data, we computed life expectancy for US adults by social determinants such as education, income/poverty level, occupation, and housing tenure.

Methods: We analyzed the 1997-2014 National Health Interview Survey prospectively linked to mortality records in the National Death Index (N=1,146,271). Standard life table methodologies were used to compute life expectancy and other life table functions at various ages according to socioeconomic variables stratified by sex and race/ethnicity.

Results: Adults with at least a Master's degree had 14.7 years higher life expectancy at age 18 than those with less than a high school education and 8.3 years higher life expectancy than those with a high school education. Poverty was inversely related to life expectancy. Individuals living in poverty had 10.5 years lower life expectancy at age 18 than those with incomes $\geq 400\%$ of the poverty threshold. Laborers and those employed in craft and repair occupations had, respectively, 10.9 years and 8.6 years lower life expectancy at age 18 than those with professional and managerial occupations. Male and female renters had, respectively, 4.0 years and 4.6 years lower life expectancy at age 18 than homeowners. Women in the most advantaged socioeconomic group outlived men in the most disadvantaged group by 23.5 years at age 18.

Conclusions and Global Health Implications: Marked socioeconomic gradients in US life expectancy were found across all sex and racial/ethnic groups. Adults with lower education, higher poverty levels, in manual occupations, and with rental housing had substantially lower life expectancy compared to their counterparts with higher socioeconomic position.

Key words: • Life expectancy • Education • Poverty • Occupation • Housing Tenure • Social determinants • Longitudinal

1. Introduction

Life expectancy has long been considered an important indicator of a nation's health and well-being and human development.^{1,3} For over three decades, reducing health inequalities and increasing life expectancy among Americans have been the two most important health policy goals for the United States (US).^{1,4} Although life expectancy estimates for the US are routinely reported by sex, race/ethnicity, rural-urban residence, and geographic area,⁵⁻⁸ they are not readily available by individual measures of socioeconomic status (SES). A number of studies have shown persistent or widening socioeconomic disparities in life expectancy over time both in the US and other Western nations such as Canada, the United Kingdom, Australia, and New Zealand.^{1,9-14} Life expectancy disparities have widened as people in higher SES groups or in more affluent communities have experienced larger gains in life expectancy than their disadvantaged counterparts.⁹⁻¹¹

Many of these studies have used area-based socioeconomic deprivation measures to study disparities in life expectancy in the absence of patient-level socioeconomic data in administrative databases, including the vital statistics-based national mortality database in the US.^{1,6,9,10} Few studies have analyzed variations in life expectancy according to individual SES measures, using longitudinal cohort data for the US.¹⁵⁻¹⁸ Efforts have been made to estimate life expectancy using educational attainment data on the death certificate, but the quality of education data, especially for decedents aged 65 years and older, remains poor and unreliable.^{5,19} Prospective linkages of population surveys and census cohorts with disease registries and mortality records have enabled recent studies to examine differentials in life expectancy by individual or household income, education, and occupation,¹⁵⁻¹⁷ but none have tackled the issue of life expectancy disparities using a wide range of individual-level social determinants.

To address the continuing gap in research on life expectancy disparities by individual-level SES, we examine variations in life expectancy among US adults with different levels of education, income/poverty status, occupations, and housing tenure (home

ownership vs. renting house) across gender and racial/ethnic groups, using a nationally representative longitudinal dataset containing 18-years of mortality follow-up. Assessing inequalities in life expectancy according to key social determinants such as education, poverty, employment, and housing status is important in that it provides information on the extent to which life expectancy can be improved among various socioeconomic and demographic groups in a given population. Monitoring social inequalities in leading health indicators, such as life expectancy, is important for policy formulation and to set and support targets for reducing health disparities and achieving health equity.^{6,11,12}

Life expectancy is a summary measure of mortality that can be used to document both absolute and relative inequalities in survival between social groups and populations with low, medium, and high levels of socioeconomic position.^{1,8,9} It shows the effects of excess mortality risks during childhood, youth, working ages, and old age as well as those from major communicable and non-communicable diseases and injuries. The aim of our study is to estimate SES disparities in life expectancy across gender and major racial/ethnic groups in the United States during 1997-2014.

2. Methods

The data source for this study was the 1997-2014 National Health Interview Survey (NHIS) prospectively linked to the National Death Index (NDI).²⁰ NHIS is a nationally representative, cross-sectional household interview survey that provides socio-economic, demographic, and health characteristics of the US civilian, non-institutionalized population. We used the public-use linked NHIS-NDI mortality file, developed by the National Center for Health Statistics, that contains 18 years of mortality follow-up data from the date of survey participation through December 31, 2014.²¹

The study sample was restricted to adults aged 18 years and older in the database as the public-use linked file did not include deaths among those aged under 18 at baseline. The sample ineligible for mortality follow-up was eliminated from the analysis. The final pooled sample size was 1,146,271. Each of the four SES variables selected for life table construction had missing

data: education (1.56%), poverty status (20.07%), occupation (the category for unemployed and those outside the labor force (62.49%)), and housing tenure (1.16%). We computed life expectancy estimates only for the known categories of the SES variables.

Follow-up time for individuals who died during the study period was defined by the number of months from the month/year of interview to the month/year of death. Since the NHIS-NDI file provides only the quarter of death, we assumed that death occurred in the middle month of the quarter; February, May, August, or November.²² The mean follow-up time for the sample was 8.2 years.

The four SES variables were measured as follows. Educational attainment consisted of five categories: less than high school diploma, high school diploma, some college, Bachelor's degree, and Master's degree or higher. Poverty status, defined as the ratio of family income to poverty threshold consisted of 5 categories: <100%, 100-199%, 200-299%, 300-399%, and ≥400%. Housing tenure included two categories: homeowners and renters. Detailed occupation categories were collapsed into 5 broad occupational groups: professional and managerial, sales/ clerical and technical support, service, craft and repair, and laborers. These broad occupational groups, derived from the major occupational groups defined by the Census Bureau, are consistent with previously defined social class positions of upper white collar, lower white collar, upper blue collar, and lower blue collar jobs.²³

We used the standard life table methodology to calculate life expectancy at age 18 and subsequent ages along with standard errors.^{24,25} Specifically, life expectancy was estimated by converting age-specific mortality rates (for 14 age groups: 18-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, and ≥85 years) into life-table probabilities of dying, allowing computation of various life-table functions. Age-specific mortality rates were computed based on person-years of exposure for each SES category. In computing person-years for age-specific mortality rates, deaths were assumed to occur uniformly throughout the follow-up period rather than being clustered in the first part of the period. We tested for differences in

life expectancy estimates by SES levels across gender, race/ethnicity, and age.

3. Results

3.1. Educational Disparities in Life Expectancy

Table 1 presents life expectancy by educational attainment for the total population, males, females, and three racial/ethnic groups. Educational attainment was positively and consistently related to life expectancy for all groups except Hispanics. Adults with at least a Master's degree had a life expectancy of 61.4 years at age 18, 14.7 years higher life expectancy than those with less than a high school education (46.7 years), and 8.3 years higher life expectancy than those with a high school education (53.1 years). Persons with a Master's degree or higher had one year higher life expectancy at age 18 than those with a bachelor's degree. Similar educational patterns in life expectancy can be noted at ages 45 and 65. Educational differentials in life expectancy were larger for men than for women (Figure 1).

Educational differentials in life expectancy were larger for non-Hispanic Blacks than for non-Hispanics Whites and Hispanics. The difference in life expectancy at age 18 between persons with at least a Master's degree and those with less than a high school education was 17.7 years for non-Hispanic Blacks, 16.2 years for non-Hispanic Whites, and 10.1 years for Hispanics. For educational categories from less than high school to bachelor's degree, blacks had significantly lower life expectancy than non-Hispanic Whites and Hispanics. However, at age 18, non-Hispanic Blacks with at least a Master's degree had a life expectancy of 62.5 years, significantly higher than the life expectancy of 60.1 and 61.8 years for Hispanics and Non-Hispanic Whites with similar educational attainment.

3.2. Disparities in Life Expectancy by Income/ Poverty Level

Higher poverty levels were associated with lower life expectancy for each age, gender, and racial/ethnic group (Table 2). Compared to those with incomes ≥400% of the poverty threshold, individuals living in poverty and those with family incomes at 100-199% of the poverty level had, respectively, 10.5 years and

Table 1: Estimated life expectancies at selected ages at baseline by education, United States, 1997-2014

	Both Sexes		Male		Female	
	LE	SE	LE	SE	LE	SE
Sample size	1,128,409		531,943		596,466	
Age 18						
Less than high school	46.70	0.11	44.03	0.15	49.51	0.15
High school diploma	53.13	0.08	50.31	0.12	55.77	0.11
Some college	56.20	0.09	53.09	0.13	58.94	0.12
Bachelor's degree	60.40	0.12	58.23	0.17	62.80	0.18
Master's degree or higher	61.39	0.25	59.89	0.36	63.59	0.35
Age 45						
Less than high school	25.55	0.08	23.79	0.11	27.24	0.12
High school diploma	30.32	0.07	28.25	0.10	31.99	0.09
Some college	32.40	0.08	29.91	0.11	34.54	0.11
Bachelor's degree	35.22	0.11	33.40	0.15	37.33	0.17
Master's degree or higher	36.26	0.14	34.84	0.18	38.38	0.22
Age 65						
Less than high school	13.34	0.06	12.16	0.09	14.32	0.08
High school diploma	16.28	0.06	14.93	0.09	17.18	0.08
Some college	17.38	0.08	15.59	0.11	18.80	0.11
Bachelor's degree	18.81	0.11	17.54	0.15	20.29	0.16
Master's degree or higher	19.51	0.13	18.64	0.17	21.00	0.22
	NHW		NHB		Hispanics	
Sample size	686,533		151,729		224,222	
Age 18						
Less than high school	45.55	0.18	44.82	0.30	49.93	0.18
High school diploma	53.34	0.10	52.64	0.22	56.10	0.27
Some college	56.46	0.10	55.99	0.29	58.12	0.36
Bachelor's degree	60.42	0.14	59.57	0.49	60.64	0.55
Master's degree or higher	61.76	0.26	62.53	0.60	60.05	0.82
Age 45						
Less than high school	23.17	0.13	23.57	0.21	29.94	0.16
High school diploma	29.97	0.08	30.06	0.20	34.45	0.27
Some college	32.12	0.09	32.67	0.28	35.58	0.37
Bachelor's degree	34.92	0.12	34.66	0.47	36.29	0.53
Master's degree or higher	36.11	0.15	36.91	0.58	35.74	0.61
Age 65						
Less than high school	11.94	0.08	13.20	0.15	16.61	0.14
High school diploma	15.71	0.06	17.43	0.20	20.36	0.28
Some college	16.93	0.08	18.66	0.30	20.55	0.39
Bachelor's degree	18.26	0.12	19.56	0.49	19.85	0.54
Master's degree or higher	19.14	0.14	21.49	0.59	18.84	0.60

LE=Life expectancy, SE=standard error, NHW=non-Hispanic Whites, NHB=non-Hispanic Blacks

Socioeconomic Status and Life Expectancy

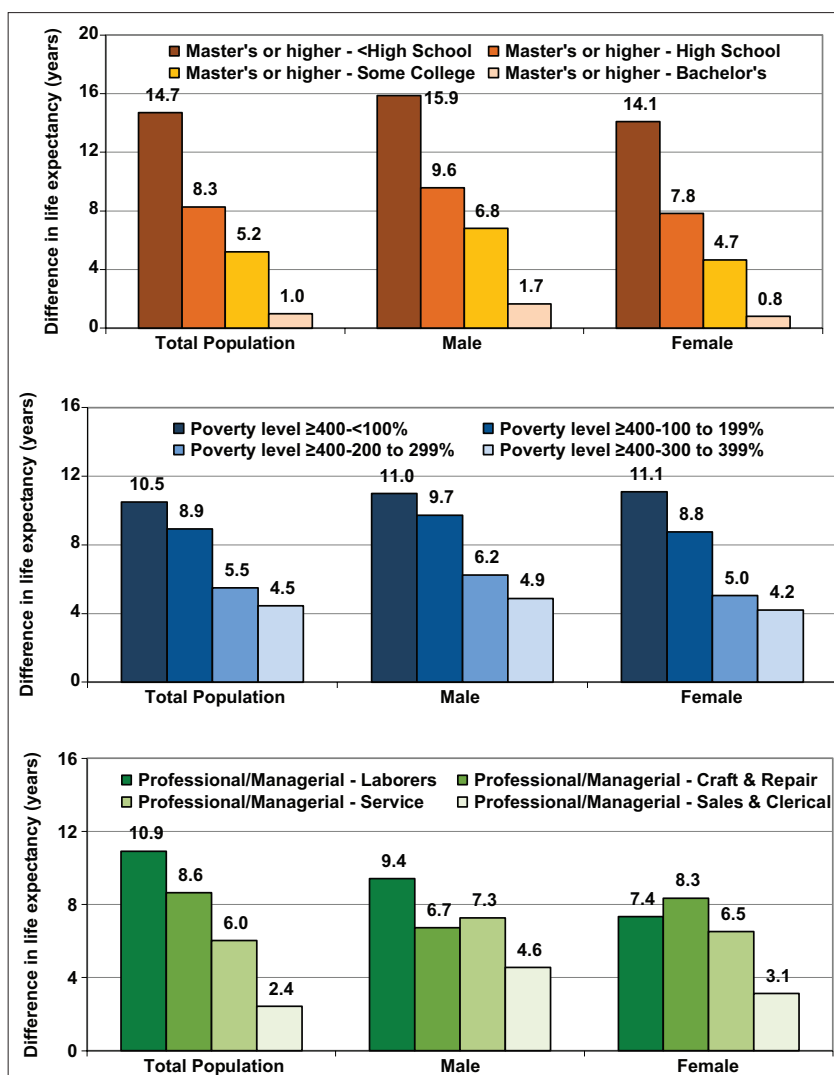


Figure 1: Differences in Life Expectancy at Age 18 Across Education, Poverty, and Occupation Groups, United States, 1997-2014
Gradients in life expectancy by education, poverty level, and occupation were statistically significant at $p < 0.001$. All life expectancy differences between the highest socioeconomic category and other categories were statistically significant at $p < 0.01$, except for the difference between Master's degree or higher and bachelor's degree for women ($p < 0.05$)

8.9 years lower life expectancy at age 18. Income/poverty differentials in life expectancy were similar for men and women (Figure 1). At age 65, men with incomes $\geq 400\%$ of the poverty threshold had a life expectancy of 18.0 years, 3.9 years longer than that for men living in poverty (14.1 years). At age 65, women with incomes $\geq 400\%$ of the poverty threshold

had a life expectancy of 20.5 years, 5.1 years longer than that for women living in poverty (15.4 years). At each age and income/poverty level, women had significantly higher life expectancy than men.

Income/poverty differentials in life expectancy were larger for non-Hispanic Blacks and non-

Table 2: Estimated life expectancies at selected ages at baseline by poverty status¹, United States, 1997-2014

	Both Sexes		Male		Female	
	LE	SE	LE	SE	LE	SE
Sample size	916,190		434,443		481,747	
Age 18						
<100%	49.20	0.13	46.30	0.21	51.35	0.17
100-199%	50.78	0.11	47.57	0.16	53.69	0.15
200-299%	54.20	0.12	51.06	0.17	57.40	0.16
300-399%	55.24	0.14	52.41	0.19	58.23	0.19
≥400%	59.70	0.10	57.29	0.13	62.44	0.14
Age 45						
<100%	26.82	0.12	25.03	0.19	28.10	0.16
100-199%	27.88	0.10	25.60	0.14	29.80	0.13
200-299%	30.69	0.10	28.33	0.14	33.00	0.15
300-399%	31.28	0.12	29.07	0.17	33.57	0.17
≥400%	35.20	0.08	33.37	0.11	37.26	0.12
Age 65						
<100%	14.91	0.11	14.07	0.18	15.39	0.14
100-199%	14.76	0.08	13.26	0.11	15.84	0.10
200-299%	16.42	0.09	14.79	0.12	17.97	0.13
300-399%	16.42	0.11	15.01	0.15	17.85	0.16
≥400%	19.17	0.09	18.01	0.11	20.47	0.13
	NHW		NHB		Hispanics	
Sample size	557,459		121,717		182,780	
Age 18						
<100%	48.14	0.21	47.95	0.27	52.00	0.27
100-199%	50.41	0.15	50.76	0.27	52.98	0.24
200-299%	54.13	0.14	55.11	0.35	55.75	0.34
300-399%	55.30	0.16	55.36	0.45	57.28	0.56
≥400%	59.76	0.10	59.63	0.41	59.13	0.39
Age 45						
<100%	25.12	0.18	25.34	0.24	30.58	0.26
100-199%	26.58	0.13	27.63	0.24	31.45	0.23
200-299%	29.98	0.12	31.60	0.32	33.85	0.32
300-399%	30.91	0.14	31.60	0.42	35.09	0.57
≥400%	34.93	0.09	35.66	0.38	35.83	0.37
Age 65						
<100%	13.51	0.16	14.37	0.22	17.13	0.25
100-199%	13.91	0.09	15.16	0.20	17.33	0.21
200-299%	15.78	0.10	17.80	0.31	19.28	0.33
300-399%	15.92	0.12	17.35	0.44	20.76	0.62
≥400%	18.71	0.09	20.93	0.42	20.34	0.39

LE=Life expectancy, SE=standard error, NHW=non-Hispanic Whites, NHB=non-Hispanic Blacks.¹Poverty status is the ratio of family income to poverty threshold (%)

Hispanics Whites than for Hispanics. However, within each income/poverty stratum except for the most affluent category, Hispanics had higher life expectancy at age 18 than Non-Hispanic Whites and Non-Hispanic Blacks. For the highest-income category, the three racial/ethnic groups had similar life expectancies at age 18 (Table 2).

3.3. Occupational Disparities in Life Expectancy

Life expectancy at age 18 was highest among adults employed in professional and managerial occupations (64.0 years), followed by those in sales/clerical/technical support occupations (61.6 years), service occupations (58.0 years), craft and repair occupations (55.4 years), and laborers (53.1 years) [Table 3]. Occupational differentials in life expectancy were larger for men than for women (Figure 1), and within each occupational category, women had substantially higher life expectancy than men. Occupational disparities in life expectancy were larger for non-Hispanic Blacks than for non-Hispanic Whites and Hispanics. Non-Hispanic Blacks in professional and managerial occupations had the highest life expectancy at age 18 (66.1 years), at least two years longer than their non-Hispanic White counterparts (63.9 years) and Hispanic counterparts (64.1 years) [Table 3].

3.4. Disparities in Life Expectancy by Housing Tenure (Homeownership vs. Renting)

At age 18, life expectancy of homeowners was 4.1 years longer than that for renters (55.2 vs. 51.1 years) [Table 4]. The life expectancy gap by housing tenure was greater for women than for men, and for non-Hispanic Whites than for non-Hispanic Blacks and Hispanics. At age 18, female homeowners had a life expectancy of 57.9 years, 5.4 years longer than the life expectancy of 52.5 years for male homeowners. Female renters had a life expectancy of 53.3 years, compared with the life expectancy of 48.6 years for male renters.

3.5. Disparities in Life Expectancy by Socioeconomic Advantage/Disadvantage

At age 18, adults in the most-advantaged socioeconomic group had a life expectancy of 63.7 years, 17.5 years longer than the life expectancy

Socioeconomic Status and Life Expectancy

Table 3: Estimated life expectancies at selected ages at baseline by occupation¹, United States, 1997-2014

	Both Sexes		Male		Female	
	LE	SE	LE	SE	LE	SE
Sample size	418,332		195,585		222,747	
Age 18						
Professional and managerial	64.01	0.16	60.97	0.22	67.00	0.22
Sales/clerical and tech support	61.58	0.16	56.41	0.28	63.86	0.20
Service	57.98	0.20	53.70	0.32	60.49	0.25
Craft and repair	55.37	0.21	54.23	0.23	58.66	0.42
Laborer	53.09	0.32	51.55	0.35	59.65	0.73
Age 45						
Professional and managerial	39.16	0.14	36.37	0.20	41.95	0.20
Sales/clerical and tech support	37.63	0.15	33.08	0.26	39.54	0.18
Service	34.83	0.18	31.39	0.29	36.68	0.23
Craft and repair	33.07	0.17	32.08	0.20	35.42	0.33
Laborer	30.95	0.27	29.79	0.30	35.72	0.66
Age 65						
Professional and managerial	23.28	0.14	21.05	0.19	25.58	0.20
Sales/clerical and tech support	22.78	0.14	19.25	0.25	24.05	0.16
Service	20.85	0.17	18.12	0.29	22.11	0.21
Craft and repair	19.68	0.16	18.81	0.19	21.24	0.27
Laborer	18.16	0.26	17.26	0.28	21.62	0.62
	NHW		NHB		Hispanics	
Sample size	268,551		59,810		68,486	
Age 18						
Professional and managerial	63.90	0.17	66.12	0.60	64.07	0.71
Sales/clerical and tech support	61.71	0.19	62.24	0.59	64.01	0.73
Service	57.43	0.26	57.00	0.43	62.53	0.58
Craft and repair	55.58	0.25	55.95	0.59	56.82	0.54
Laborer	53.40	0.40	52.92	0.71	54.86	0.81
Age 45						
Professional and managerial	38.77	0.15	42.12	0.57	40.19	0.69
Sales/clerical and tech support	37.29	0.16	38.76	0.58	41.46	0.75
Service	33.63	0.24	33.77	0.39	40.89	0.58
Craft and repair	32.48	0.20	33.11	0.48	36.43	0.51
Laborer	30.31	0.34	30.05	0.61	35.28	0.76
Age 65						
Professional and managerial	22.67	0.15	27.98	0.56	24.92	0.70
Sales/clerical and tech support	22.29	0.15	24.95	0.61	27.01	0.78
Service	19.75	0.22	20.68	0.37	26.29	0.60
Craft and repair	18.91	0.18	20.83	0.46	23.13	0.50
Laborer	17.43	0.32	18.19	0.62	21.84	0.73

LE=Life expectancy; SE=standard error; NHW=non-Hispanic Whites, NHB=non-Hispanic Blacks. ¹Occupation was recoded based on a modified variable of the 1995 revised Standard Occupational Classification-based codes, offering a consistent long-term classification of occupations

Table 4: Estimated life expectancies at selected ages at baseline by housing tenure, United States, 1997-2014

	Both Sexes		Male		Female	
	LE	SE	LE	SE	LE	SE
Sample size	1,132,919		534,577		598,342	
Age 18						
Renter	51.10	0.08	48.57	0.12	53.32	0.11
Owner	55.21	0.05	52.53	0.08	57.87	0.07
Age 45						
Renter	28.06	0.08	26.28	0.12	29.50	0.11
Owner	31.58	0.04	29.70	0.06	33.37	0.06
Age 65						
Renter	14.84	0.08	13.79	0.12	15.52	0.10
Owner	16.41	0.04	15.16	0.05	17.51	0.05
	NHW		NHB		Hispanics	
Sample size	687,456		152,534		226,793	
Age 18						
Renter	50.65	0.12	50.34	0.18	53.18	0.19
Owner	55.91	0.06	53.45	0.17	54.13	0.16
Age 45						
Renter	26.72	0.11	27.07	0.17	31.71	0.20
Owner	31.50	0.05	30.41	0.14	32.48	0.14
Age 65						
Renter	13.70	0.10	14.62	0.17	17.66	0.20
Owner	16.01	0.04	16.50	0.12	18.04	0.14

LE=Life expectancy, SE=standard error

of 46.2 years for the most-disadvantaged group (Figure 2). The corresponding group difference was 18.5 years for men and 18.2 years for women. Women in the most-advantaged socioeconomic group outlived men in the most-disadvantaged group by 23.5 years at age 18. Large life expectancy differences between the most-advantaged and most-disadvantaged socioeconomic groups can also be noted at ages 45 and 65.

4. Discussion

In this large prospective study of 1,146,271 US adults using a mortality follow-up of 18 years, we found that adults with lower SES levels had substantially lower life expectancy, with a life expectancy gap of almost 18 years between the lowest and highest SES groups. Strikingly large socioeconomic

disparities in life expectancy existed for both men and women and for non-Hispanics Whites, non-Hispanic Blacks, and Hispanics. A particularly novel feature of our study is that it provides recent life expectancy estimates for Americans according to four different individual-level SES measures of education, income, occupation, and housing tenure. Such a comprehensive range of socioeconomic inequalities in life expectancy has not been previously reported in the same study, to the best of our knowledge.

The findings of our study are consistent with those from previous studies of individual-level socioeconomic differentials in life expectancy.^{12, 15, 17, 18, 26, 27} Rogot and colleagues found a difference in life expectancy at age 25 of 6 years for white men and 5 years for white women between the highest (master's degree or higher) and lowest (less than high school) education levels, much smaller than the education differentials shown in our study.¹⁵ Consistent with our study, higher income was associated with higher life expectancy in the Rogot et al. study; however, the corresponding income/poverty differential in life expectancy in our study (11 years) was substantially greater than the difference of 5 years reported in their study.¹⁵ Although SES groups were slightly different, education and income/poverty differences (the highest SES group – the lowest SES group) in male and female life expectancy were much smaller in Canada (5 to 8 years)¹² compared with 11 to 16 years noted in our US study. In a German study,²⁶ differences in life expectancy at age 40 between the highest and lowest educated men and women were 6.3 and 2.3 years respectively, considerably smaller than the corresponding difference of 11 years for men and women in our study. Income differences in life expectancy were also smaller for Germany than for the US.²⁶

Occupational differences in life expectancy in Germany were similar to those found in our study, with life expectancy of German men at age 40 ranging from 30 years for manual, unskilled workers to 39 years for those in professional and technical occupations.²⁶ In England and Wales, the difference in life expectancy at birth between professional/managerial occupations and routine manual

Socioeconomic Status and Life Expectancy

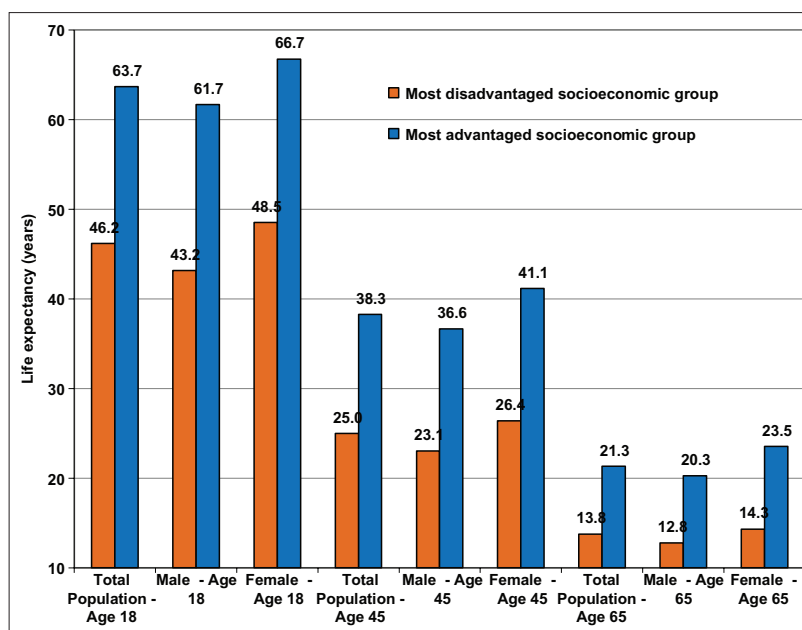


Figure 2: Life Expectancy of the Most Disadvantaged and Most Advantaged Socioeconomic Groups by Age and Sex, United States, 1997-2014

The most disadvantaged socioeconomic group consisted of adults with less than a high school education and family income below the poverty level. The most advantaged socioeconomic group consisted of adults with a master's or higher degree and family income at or above 400% of the poverty threshold. Differences in life expectancy between the most advantaged and most disadvantaged socioeconomic groups across all sex and age groups were statistically significant at $p < 0.001$.

occupations (laborers, lorry drivers, and bar staff) was 6 years for men and 4 years for women.²⁷ This is substantially smaller than the occupational difference in life expectancy noted for the US in our study. In the 1979-2011 US National Longitudinal Mortality Study, homeowners at age 20 had a life expectancy of 54.8 years, 3.4 years longer than the life expectancy of 51.4 years for renters.¹⁶ In our study, the difference in life expectancy at age 18 between homeowners and renters was 4.1 years.

Our study shows large socioeconomic differences in life expectancy among US men and women, which appeared to have increased over time in both absolute and relative terms when compared with similar estimates for comparative US populations in earlier time periods. Differences in material, psychosocial (stress, low control at work, home, or over life circumstances, social support, and social integration), lifestyle, and healthcare (health insurance, access to preventive health services,

stage of disease at diagnosis, and treatment) factors may partly account for SES differences in life expectancy.^{1,9,28} Lower levels of education, income, occupational social class, and homeownership have been associated with higher prevalence of smoking, obesity, physical inactivity, heavy alcohol consumption, poor diet, and lower access to health services.^{1,6,29,30} Smoking rates have decreased more rapidly among those in higher SES groups, which has partly contributed to the widening disparities in life expectancy, all-cause mortality, and mortality from major causes of death such as cardiovascular disease (CVD) and cancer in the US.^{1,29,31} Indeed, smoking and obesity-related causes such as CVD, cancer, COPD, and diabetes and injuries may account for 50% to 75% of the life expectancy disparities between socioeconomic groups.^{1,9,29} However, a formal cause-of-death decomposition analysis is needed to better explain SES disparities in life expectancy shown here.

4.1. Limitations

This study has limitations. First, our study only contains NHIS samples eligible for linkage to the NDI. Excluding samples ineligible for linkage or unmatched records in the two databases may have affected life expectancy estimates. Second, our study did not conduct a life table decomposition analysis, which would have allowed us to partition socioeconomic disparities in life expectancy due to excess mortality in specific age groups and causes of death. Third, although our analysis of life expectancy does stratify by gender and race/ethnicity, it does not account for differences in other demographic characteristics such as marital status, nativity/immigrant status, geographic mobility, and place of residence. In our study, housing tenure was defined as a dichotomous variable, which does not distinguish renters who live in public or social housing or receive rental or housing assistance from a government program from those who do not receive any rental assistance. Renters receiving housing assistance or those living in public/social housing experience much higher risks of morbidity and mortality than homeowners and other renters.^{16,32,33} Fourth, since the NHIS excludes the institutionalized population, who may have higher levels of socioeconomic disadvantage, morbidity, and mortality, life expectancy for those at lower SES levels may have been overestimated, leading to possible underestimation of SES inequalities in life expectancy reported here. Fifth, all SES variables in the NHIS-NDI database were time-fixed at the baseline as of the survey date. Although education is fairly stable after age 25 for most adults over the life course, other measures of SES such as income/poverty status, occupation and employment status, and housing tenure may have changed over the long mortality follow-up of 18 years, potentially influencing the magnitude and patterns in life expectancy associated with these measures. Further studies are needed to evaluate the temporal robustness of socioeconomic patterns in life expectancy using longitudinal datasets with time-varying covariates and/or shorter mortality follow-ups.

5. Conclusions and Global Health Implications

Marked socioeconomic gradients in US life expectancy were found across all sex and racial/ethnic groups. Adults with lower education, higher poverty level, in manual occupations, and with rental housing had substantially lower life expectancy compared to their counterparts with higher socioeconomic position. Socioeconomic inequalities in life expectancy most likely reflect inequalities in material and social conditions as well as those in behavioral and healthcare factors.^{1,9,28} As life expectancy has improved around the globe, persistent or growing social inequalities in life expectancy are not only characteristic of high-income countries but also of the developing world.³⁴ Social policies aimed at reducing disparities in the broader, more fundamental social determinants such as education, poverty, affordable housing, employment, work environment, labor market opportunities, and transportation, along with public health measures that target reductions in smoking, obesity, inadequate access to healthy foods, and improvements in access to health services have the potential to reduce health and life expectancy inequalities between high and low SES groups.^{1,9,10}

Compliance with Ethical Standards

Conflicts of Interest: None. **Financial Disclosure:** None to report. **Funding/Support:** Hyunjung Lee was supported in part by an appointment to the Research Participation Program at the Health Resources & Services Administration - Office of Health Equity (HRSA-OHE), administered by the Oak Ridge Institute for Science and Education (ORISE) through an interagency agreement between the US Department of Energy and HRSA. **Ethical approval:** The study was exempt from Institutional Review Board approval as it utilized a de-identified public use dataset. **Disclaimer:** The views expressed in this article are those of the author and do not necessarily reflect the official policies of the US Department of Health and Human Services or the Health Resources and Services Administration.

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Key Messages

- ▶ This study estimated life expectancy of 1,146,271 American adults according to their education and income levels, occupation, and housing tenure.
- ▶ Americans with an advanced degree (Master's degree or higher) had 14.7 years higher life expectancy at age 18 than those with less than a high school education.
- ▶ Poor Americans had 10.5 years lower life expectancy at age 18 than those with incomes at or above 400% of the poverty threshold. Laborers and those employed in craft and repair occupations had, respectively, 10.9 years and 8.6 years lower life expectancy at age 18 than those in professional and managerial occupations.
- ▶ Among Americans with an advanced degree, non-Hispanic Blacks (62.5 years) had a higher life expectancy at age 18 than Hispanics (60.1) and Non-Hispanic Whites (61.8).
- ▶ Male and female renters had, respectively, 4.0 years and 4.6 years lower life expectancy at age 18 than homeowners. Women in the most advantaged socioeconomic group outlived men in the most disadvantaged socioeconomic group by 23.5 years at age 18.

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Housing Table 2. Household Energy Use and Spending in the last 12 Months, by Select Characteristics: United States

Source: U.S. Census Bureau Household Pulse Survey, Cycle 02.

Note: These data are experimental. Users should take caution using estimates based on subpopulations of the data – sample sizes may be small and the standard errors may be large.**

Total Population 18 Years and Older

Select characteristics	Total*	Household reduced or forwent expenses for basic household necessities, such as medicine or food, in order to pay an energy bill					Almost every month
		Almost every month	Some months	1 or two months	Never	Did not report	
Total	256,311,560	21,544,100	28,585,565	21,640,334	137,486,848	47,054,712	14,019,730
Age							
18 - 24	18,754,825	1,360,569	1,986,804	1,949,122	8,237,720	5,220,611	975,437
25 - 39	74,241,688	7,317,086	9,134,718	7,384,668	36,238,383	14,166,834	3,810,815
40 - 54	65,251,738	6,889,019	8,462,701	5,891,716	32,244,465	11,763,837	3,282,106
55 - 64	42,184,846	3,359,927	4,891,657	3,430,991	23,220,877	7,281,394	2,857,753
65 and above	54,648,593	2,570,896	4,085,816	2,969,237	37,027,758	7,994,886	2,999,151
Sex at birth							
Male	124,903,432	9,863,593	12,941,950	10,261,712	68,631,929	23,204,247	6,812,077
Female	131,408,128	11,680,507	15,643,615	11,378,622	68,854,919	23,850,465	7,207,654
Gender							
Cisgender male	58,974,265	4,559,683	6,602,677	5,109,175	32,528,109	10,174,621	3,253,854
Cisgender female	61,182,038	5,470,813	7,004,174	5,070,765	33,217,951	10,418,336	3,187,327
Transgender	1,434,631	142,533	194,333	116,184	607,948	373,634	143,799
None of these	2,007,132	238,359	149,722	107,369	957,725	553,957	219,545
Did not report	132,713,493	11,132,712	14,634,660	11,236,842	70,175,116	25,534,164	7,215,205
Sexual orientation							
Gay or lesbian	8,166,640	830,656	909,442	615,138	4,449,391	1,362,013	455,219
Straight	221,226,062	18,156,828	23,956,991	18,495,584	120,920,165	39,696,494	11,800,817
Bisexual	12,455,885	1,161,706	1,881,881	1,465,504	6,264,603	1,682,190	791,443
Something else	5,798,579	625,129	815,593	687,467	2,726,019	944,371	437,627
I don't know	4,865,091	510,736	685,071	191,102	2,024,187	1,453,995	401,396
Did not report	3,799,303	259,044	336,587	185,540	1,102,483	1,915,650	133,229
Lesbian, Gay, Bisexual and Transgender							
Yes	21,339,967	2,088,254	2,862,068	2,160,368	10,906,349	3,322,927	1,334,023
No	105,505,410	8,648,217	11,452,629	8,726,637	58,410,123	18,267,803	5,480,839
Other	5,771,793	497,856	807,430	499,613	2,643,926	1,322,969	492,550
Did not report	123,694,390	10,309,773	13,463,438	10,253,716	65,526,450	24,141,014	6,712,318
Hispanic origin and Race							
Hispanic or Latino (may be of any race)	46,076,504	5,322,310	6,906,809	5,178,909	18,045,838	10,622,638	2,744,739
White alone, not Hispanic	155,908,031	10,772,991	14,870,909	11,922,506	93,944,638	24,396,986	8,348,946
Black alone, not Hispanic	29,940,051	3,114,868	4,039,823	2,487,857	12,686,595	7,610,908	1,539,136
Asian alone, not Hispanic	12,789,635	809,139	1,250,959	645,622	7,730,634	2,353,281	546,016
Two or more races + Other races, not Hispanic	11,597,338	1,524,791	1,517,064	1,405,441	5,079,143	2,070,898	840,893
Education							
Less than high school	21,702,760	3,023,834	2,980,559	2,286,576	7,736,339	5,675,451	1,681,247
High school or GED	74,506,380	7,736,882	10,193,071	6,839,836	32,650,351	17,086,239	4,375,511
Some college/associate's degree	74,764,183	7,416,525	9,745,387	7,092,577	36,379,617	14,130,077	4,330,772
Bachelor's degree or higher	85,338,237	3,366,859	5,666,548	5,421,345	60,720,541	10,162,945	3,632,201
Marital status							
Married	140,139,921	9,491,947	13,566,952	11,153,171	83,198,835	22,729,015	6,793,266
Widowed	11,879,836	877,484	1,429,449	870,229	6,665,969	2,036,705	819,136
Divorced/separated	35,640,367	4,628,789	4,796,222	3,060,277	16,356,365	6,798,714	2,752,022
Never married	66,810,785	6,453,374	8,685,494	6,515,055	30,785,055	14,371,806	3,623,727
Did not report	1,840,651	92,506	107,447	41,602	480,624	1,118,472	31,579
Household size							
1 person in the household	24,908,789	2,023,180	2,715,307	1,803,942	14,891,583	3,474,776	1,695,479
2 people in the household	82,091,296	5,340,074	7,117,068	5,813,082	51,480,834	12,340,238	4,437,885
3 people in the household	48,885,919	4,268,504	6,048,239	4,130,343	25,688,462	8,750,371	2,779,331
4 people in the household	46,240,580	3,696,294	5,187,265	3,694,998	23,965,567	9,696,457	1,938,248

5 people in the household	27,627,608	2,613,363	4,038,870	3,249,064	12,116,437	5,609,874	1,479,942
6 people in the household	13,188,173	1,513,542	2,050,055	1,282,110	5,090,193	3,252,273	755,564
7 or more people in the household	13,369,195	2,089,144	1,428,761	1,666,795	4,253,772	3,930,723	933,281
Presence of children under 18 years old							
Children in household	95,626,653	9,361,123	11,553,727	9,655,268	43,162,075	21,894,460	4,701,094
No children	160,684,907	12,182,977	17,031,838	11,985,067	94,324,774	25,160,252	9,318,636
Respondent or household member experienced loss of employment income in last 4 weeks							
Yes	34,062,641	6,651,019	6,536,923	4,053,824	10,676,342	6,144,533	3,113,998
No	214,606,198	14,816,505	21,955,021	17,541,560	126,620,602	33,672,510	10,829,588
Did not report	7,642,721	76,576	93,621	44,950	189,903	7,237,669	76,144
Respondent employed in the last 7 days							
Yes	151,330,365	12,228,874	17,544,001	14,067,664	84,970,825	22,519,001	7,999,690
No	96,257,836	9,215,620	10,874,301	7,456,986	51,881,111	16,829,818	5,932,095
Did not report	8,723,359	99,606	167,263	115,684	634,912	7,705,893	87,945
Household income							
Less than \$25,000	28,463,161	5,941,286	6,127,554	3,523,842	12,786,656	83,822	3,303,557
\$25,000 - \$34,999	20,610,402	3,267,360	4,443,130	2,763,989	10,042,060	93,863	1,672,298
\$35,000 - \$49,999	24,778,958	4,191,155	4,536,276	3,404,605	12,611,242	35,680	2,008,511
\$50,000 - \$74,999	32,536,021	3,363,244	5,122,721	4,234,075	19,774,620	41,361	2,423,342
\$75,000 - \$99,999	24,916,617	1,719,648	3,094,175	2,606,836	17,479,370	16,588	1,263,982
\$100,000 - \$149,999	32,169,468	1,538,128	2,811,123	2,538,617	25,213,910	67,690	1,419,962
\$150,000 - \$199,999	15,804,441	411,328	751,708	995,576	13,612,854	32,975	628,259
\$200,000 and above	19,643,805	323,301	407,289	561,481	18,338,647	13,087	725,944
Did not report	57,388,687	788,650	1,291,590	1,011,313	7,627,489	46,669,645	573,874
Active duty military*							
Serving on active duty	1,080,140	100,403	44,925	44,824	633,926	256,062	68,603
Serving in Reserve or National Guard	760,930	65,155	60,698	68,589	426,552	139,937	46,213
Spouse serving on active duty	745,342	77,556	69,568	33,863	438,350	126,005	44,706
Spouse serving in Reserve or National Guard	766,857	66,763	54,080	55,294	330,196	260,524	62,976
No active duty service (self or spouse)	248,112,228	21,188,446	28,338,272	21,373,534	135,520,497	41,691,480	13,745,756
Did not report	5,049,539	73,070	23,970	65,165	256,652	4,630,683	63,392
Previous military service*							
No	204,701,521	18,393,144	24,224,770	17,874,115	109,553,619	34,655,873	11,296,115
Served on active duty	16,599,908	936,452	1,493,446	1,350,939	10,546,224	2,272,847	1,018,818
Served in the Reserve or National Guard	4,637,047	307,849	449,416	430,981	2,950,931	497,869	210,164
Spouse served on active duty	12,391,704	704,372	1,189,461	868,584	7,801,490	1,827,798	653,556
Spouse served in the Reserve or National Guard	2,737,007	182,704	324,104	237,527	1,651,079	341,592	176,288
Did not report	19,257,368	1,238,873	1,180,717	1,225,581	7,633,929	7,978,268	882,356
Difficulty seeing							
No difficulty	166,836,712	11,322,404	16,621,207	14,018,398	104,916,633	19,958,069	8,150,169
Some difficulty	63,717,650	8,545,071	10,386,475	7,007,705	29,840,911	7,937,487	4,854,641
A lot of difficulty	6,629,350	1,473,579	1,510,232	586,443	2,148,599	910,497	852,279
Cannot do at all	649,632	173,624	58,049	14,990	256,028	146,942	126,328
Did not report	18,478,216	29,422	9,603	12,798	324,676	18,101,718	36,312
Difficulty hearing							
No difficulty	198,255,226	16,400,714	23,412,618	17,693,412	116,597,994	24,150,489	10,603,693
Some difficulty	33,482,953	3,852,097	4,394,053	3,321,060	18,234,626	3,681,118	2,556,327
A lot of difficulty	4,336,746	958,848	574,064	431,930	1,701,039	670,864	544,227
Cannot do at all	786,955	196,205	89,426	64,809	301,721	134,794	137,973
Did not report	19,449,680	136,237	115,403	129,123	651,469	18,417,447	177,510
Difficulty remembering or concentrating							
No difficulty	162,818,371	11,628,573	16,728,678	12,994,761	101,829,579	19,636,779	8,376,463
Some difficulty	64,963,712	7,945,635	10,034,943	7,256,374	32,109,524	7,617,236	4,254,316
A lot of difficulty	8,955,974	1,739,735	1,719,996	1,290,269	2,952,027	1,253,946	1,161,497
Cannot do at all	545,531	185,046	38,029	6,043	201,272	115,141	92,004
Did not report	19,027,973	45,111	63,918	92,887	394,445	18,431,611	135,449

Difficulty walking or climbing stairs							
No difficulty	181,818,308	13,735,609	19,749,213	16,092,411	109,905,391	22,335,684	9,205,218
Some difficulty	43,803,658	5,821,630	6,928,762	4,054,168	21,983,848	5,015,250	3,435,581
A lot of difficulty	10,556,429	1,670,548	1,770,059	1,291,626	4,586,910	1,237,287	1,074,871
Cannot do at all	1,172,014	254,481	72,650	97,105	590,477	157,302	144,008
Did not report	18,961,151	61,832	64,881	105,026	420,223	18,309,190	160,053
Difficulty with self-care							
No difficulty	217,883,683	17,918,431	24,985,901	19,174,110	129,476,568	26,328,674	11,848,890
Some difficulty	16,272,858	2,838,157	2,964,837	1,849,380	6,730,292	1,890,193	1,579,187
A lot of difficulty	2,557,770	574,453	470,508	460,654	660,011	392,144	348,104
Cannot do at all	633,448	146,870	99,233	55,565	240,334	91,446	85,237
Did not report	18,963,801	66,191	65,086	100,626	379,643	18,352,255	158,313
Difficulty understanding or being understood							
No difficulty	220,534,561	18,429,189	25,745,648	19,929,255	130,278,002	26,152,467	12,159,423
Some difficulty	14,894,781	2,384,134	2,440,342	1,511,460	6,251,348	2,307,497	1,449,955
A lot of difficulty	1,535,603	486,544	314,029	86,280	423,281	225,469	190,468
Cannot do at all	495,028	113,274	25,494	49,396	214,992	91,872	78,809
Did not report	18,851,587	130,959	60,053	63,944	319,224	18,277,406	141,074

* Totals may not sum to 100% as the question allowed for multiple categories to be marked.

** The Census Bureau considers estimated coefficients of variation (standard error divided by the estimate times 100) over 30 percent to indicate potentially serious data quality issues related to sampling error.

Household kept home at a temperature that felt unsafe or unhealthy				Household was unable to pay an energy bill or unable to pay the full bill amount				
Some months	1 or two months	Never	Did not report	Almost every month	Some months	1 or two months	Never	Did not report
19,940,648	13,960,750	161,179,124	47,211,308	11,694,847	18,906,271	18,634,722	160,105,730	46,969,990
1,636,753	1,215,473	9,684,177	5,242,984	779,994	916,181	1,744,547	10,084,315	5,229,788
5,148,676	4,985,940	46,057,006	14,239,251	4,192,942	6,453,726	6,369,323	43,046,987	14,178,710
5,713,645	3,354,281	41,063,579	11,838,126	3,866,157	6,148,136	5,504,068	37,952,475	11,780,901
3,530,015	2,337,563	26,109,975	7,349,540	1,628,961	3,013,723	2,970,295	27,287,422	7,284,445
3,878,495	2,047,831	37,803,744	7,919,372	1,198,657	2,357,915	2,021,602	41,196,306	7,874,112
8,985,138	6,701,592	79,083,751	23,320,875	4,741,373	7,479,943	8,876,536	80,639,002	23,166,578
10,955,510	7,259,158	82,095,373	23,890,433	6,953,474	11,426,328	9,758,186	79,466,728	23,803,413
4,150,895	3,344,927	37,969,996	10,254,592	2,341,051	3,603,687	4,340,412	38,503,833	10,185,282
5,237,294	3,203,358	39,083,995	10,470,064	3,080,872	5,209,605	4,491,486	37,944,398	10,455,678
160,771	124,234	637,089	368,739	118,142	86,561	126,308	734,882	368,739
199,320	163,002	869,781	555,483	176,473	144,408	138,282	992,594	555,374
10,192,367	7,125,228	82,618,263	25,562,430	5,978,309	9,862,010	9,538,234	81,930,023	25,404,918
693,442	413,219	5,250,275	1,354,485	491,041	440,952	582,870	5,300,486	1,351,292
16,840,775	11,352,443	141,432,272	39,799,755	9,485,180	16,179,517	15,737,067	140,265,628	39,558,670
1,142,988	1,124,633	7,697,659	1,699,162	765,406	1,317,405	1,124,495	7,564,389	1,684,190
659,747	622,881	3,126,623	951,702	435,979	443,293	801,483	3,161,794	956,030
347,544	335,373	2,324,844	1,455,934	422,511	334,767	230,427	2,400,410	1,476,976
256,150	112,201	1,347,452	1,950,271	94,730	190,337	158,380	1,413,023	1,942,833
1,911,197	1,575,930	13,191,342	3,327,476	1,322,973	1,805,450	1,757,972	13,144,262	3,309,311
8,096,285	5,455,958	68,113,553	18,358,775	4,638,277	7,424,092	7,547,212	67,624,610	18,271,219
464,187	523,473	2,966,453	1,325,131	398,854	533,764	584,272	2,917,379	1,337,523
9,468,979	6,405,389	76,907,776	24,199,928	5,334,743	9,142,965	8,745,266	76,419,479	24,051,938
4,691,999	3,318,865	24,634,520	10,686,380	3,074,464	4,227,423	4,884,343	23,268,306	10,621,969
10,676,966	7,732,163	104,727,571	24,422,386	5,125,774	8,923,314	9,519,782	108,021,407	24,317,755
2,227,150	1,323,720	17,220,187	7,629,858	2,196,616	3,926,821	2,790,077	13,415,164	7,611,373
997,525	741,828	8,136,631	2,367,636	321,758	667,988	450,342	9,034,597	2,314,950
1,347,008	844,174	6,460,215	2,105,048	976,235	1,160,725	990,178	6,366,257	2,103,944
2,439,193	1,259,360	10,629,580	5,693,380	1,834,543	2,159,668	2,232,480	9,844,059	5,632,010
6,541,004	4,004,127	42,461,695	17,124,042	4,223,694	6,903,665	6,554,439	39,742,488	17,082,094
6,715,101	4,752,691	44,800,232	14,165,388	3,891,817	6,696,981	6,238,415	43,882,297	14,054,673
4,245,349	3,944,572	63,287,617	10,228,498	1,744,793	3,145,957	3,609,388	66,636,886	10,201,213
8,685,420	6,224,824	95,492,802	22,943,609	4,759,630	8,581,858	9,015,415	94,993,304	22,789,713
1,300,627	519,229	7,304,240	1,936,605	495,914	1,024,226	762,865	7,673,078	1,923,753
3,804,537	2,074,765	20,190,851	6,818,192	2,657,333	3,725,394	2,737,586	19,692,042	6,828,012
6,072,487	5,109,788	37,612,494	14,392,289	3,757,250	5,532,805	6,071,556	37,137,637	14,311,537
77,576	32,144	578,738	1,120,614	24,719	41,988	47,301	609,669	1,116,974
2,336,510	1,424,367	15,948,025	3,504,409	1,010,565	1,650,686	1,331,022	17,403,230	3,513,286
5,976,693	4,026,046	55,345,181	12,305,492	2,137,817	4,310,225	4,273,816	59,159,390	12,210,048
3,760,718	2,662,866	30,902,871	8,780,134	1,927,590	3,830,844	3,596,682	30,790,128	8,740,674
3,166,081	2,414,906	28,940,945	9,780,399	2,153,228	3,745,447	3,668,049	26,975,950	9,697,906

2,201,063	1,567,284	16,793,189	5,586,131	1,824,072	2,748,587	2,745,629	14,766,972	5,542,348
1,175,726	1,006,706	6,983,851	3,266,325	1,049,294	1,232,219	1,649,220	5,983,632	3,273,807
1,323,857	858,576	6,265,062	3,988,419	1,592,281	1,388,262	1,370,303	5,026,428	3,991,921
6,457,296	5,165,077	57,327,368	21,975,818	6,166,645	9,143,739	9,128,260	49,310,011	21,877,998
13,483,352	8,795,673	103,851,756	25,235,490	5,528,202	9,762,532	9,506,461	110,795,719	25,091,993
4,434,313	3,219,095	17,111,945	6,183,290	3,906,424	4,852,279	4,307,508	14,861,744	6,134,686
15,453,481	10,695,150	143,834,391	33,793,589	7,735,816	13,984,933	14,296,373	144,991,431	33,597,645
52,853	46,505	232,788	7,234,430	52,608	69,059	30,840	252,555	7,237,659
11,662,967	8,961,046	100,067,059	22,639,604	6,483,697	11,617,421	11,635,761	99,095,883	22,497,603
8,217,142	4,941,409	60,322,822	16,844,368	5,140,067	7,205,798	6,943,501	60,217,811	16,750,659
60,539	58,295	789,243	7,727,337	71,082	83,052	55,460	792,037	7,721,728
4,984,999	2,598,280	17,375,505	200,820	3,735,063	4,613,232	3,856,283	16,149,457	109,126
3,138,806	2,006,626	13,712,556	80,117	1,676,891	3,146,633	2,377,886	13,359,245	49,748
3,314,114	1,936,902	17,478,855	40,575	2,246,800	3,369,548	3,164,948	15,963,309	34,353
3,055,962	2,338,702	24,649,338	68,677	1,689,649	3,429,927	3,454,414	23,906,215	55,816
2,015,192	1,605,393	19,964,577	67,473	733,252	1,669,384	1,967,266	20,482,804	63,911
1,545,173	1,706,542	27,415,747	82,042	697,609	1,420,120	2,069,827	27,940,284	41,627
567,437	559,643	14,025,729	23,373	202,635	362,398	540,680	14,682,858	15,870
398,817	477,320	18,012,986	28,738	204,720	156,313	322,862	18,944,858	15,052
920,146	731,341	8,543,831	46,619,495	508,227	738,716	880,557	8,676,700	46,584,487
56,327	75,289	625,669	254,251	58,182	34,365	48,468	687,878	251,246
61,286	58,944	454,550	139,937	53,489	26,920	86,249	454,336	139,937
54,866	91,164	434,977	119,629	24,983	38,145	42,477	523,113	116,624
18,402	12,620	380,040	292,820	28,899	46,270	37,285	361,582	292,820
19,707,829	13,699,615	159,154,478	41,804,550	11,501,626	18,726,038	18,407,367	157,882,853	41,594,345
47,139	28,585	260,324	4,650,100	54,959	37,536	17,142	317,911	4,621,991
16,366,067	11,516,340	130,807,405	34,715,595	10,055,998	15,905,650	15,889,014	128,316,937	34,533,923
993,586	839,330	11,458,252	2,289,921	445,968	995,168	753,935	12,152,950	2,251,887
407,416	265,322	3,260,473	493,672	152,915	384,492	183,211	3,420,212	496,216
929,058	660,733	8,399,695	1,748,662	420,282	724,058	706,846	8,781,777	1,758,742
332,062	164,750	1,724,596	339,310	164,812	163,196	229,431	1,841,473	338,096
1,145,818	786,485	8,303,113	8,139,596	614,890	934,998	1,065,662	8,532,220	8,109,598
10,325,503	8,553,440	119,712,573	20,095,027	6,140,579	10,558,794	11,393,459	118,767,598	19,976,281
8,279,887	4,725,223	37,917,091	7,940,807	4,352,847	7,377,137	6,257,346	37,893,731	7,836,588
1,303,299	660,294	2,888,002	925,476	1,007,333	927,622	832,321	2,950,021	912,053
16,828	15,074	342,359	149,043	169,529	33,047	47,724	252,389	146,942
15,131	6,719	319,098	18,100,955	24,558	9,671	103,871	241,990	18,098,126
14,660,383	11,161,349	137,580,061	24,249,740	8,742,578	15,487,427	15,393,934	134,573,698	24,057,589
4,355,870	2,346,183	20,496,916	3,727,656	2,177,617	2,818,156	2,834,316	21,963,531	3,689,332
769,996	324,012	2,096,756	601,755	515,776	448,317	342,376	2,438,835	591,441
95,023	47,070	372,095	134,794	192,153	79,993	29,491	350,525	134,794
59,375	82,137	633,295	18,497,363	66,722	72,378	34,605	779,141	18,496,835
10,420,636	7,805,964	116,511,621	19,703,687	5,961,683	10,854,469	10,703,990	115,754,424	19,543,804
8,016,544	5,230,546	39,768,743	7,693,563	4,505,741	6,754,318	6,612,069	39,472,846	7,618,737
1,416,636	882,227	4,318,210	1,177,403	1,049,614	1,181,844	1,238,264	4,311,275	1,174,976
66,698	32,085	240,941	113,802	143,744	97,225	37,259	153,501	113,802
20,134	9,927	339,609	18,522,853	34,065	18,414	43,139	413,683	18,518,671

12,563,482	9,924,360	127,700,648	22,424,600	7,111,610	12,681,870	13,180,226	126,589,338	22,255,263
5,677,908	3,033,355	26,662,187	4,994,626	3,403,386	4,717,219	4,188,319	26,542,019	4,952,715
1,574,844	902,629	5,761,101	1,242,984	977,384	1,346,044	1,141,695	5,874,595	1,216,710
93,464	57,477	719,764	157,302	157,116	119,864	62,304	675,428	157,302
30,949	42,929	335,425	18,391,796	45,351	41,274	62,178	424,349	18,388,000
16,611,392	12,085,099	151,009,546	26,328,756	9,418,154	16,173,679	16,489,515	149,664,805	26,137,531
2,746,463	1,532,466	8,467,473	1,947,270	1,796,723	2,122,512	1,733,766	8,704,020	1,915,837
482,201	295,124	1,036,544	395,796	306,708	482,323	315,071	1,060,122	393,546
76,219	43,892	336,654	91,446	118,863	91,655	58,964	272,519	91,446
24,373	4,168	328,907	18,448,040	54,399	36,101	37,406	404,264	18,431,630
17,075,215	12,625,931	152,390,253	26,283,740	9,923,119	16,882,850	16,794,132	150,892,095	26,042,366
2,422,575	1,165,857	7,617,036	2,239,357	1,340,958	1,809,602	1,561,907	7,930,079	2,252,235
366,294	155,344	587,275	236,222	272,537	148,776	193,499	694,055	226,736
58,505	5,722	260,119	91,872	114,841	39,633	73,045	175,636	91,872
18,058	7,896	324,440	18,360,118	43,393	25,410	12,138	413,865	18,356,781

Housing Table 4. Household Energy Use and Spending in the last 12 Months, by Select Characteristics: Michigan

Source: U.S. Census Bureau Household Pulse Survey, Cycle 02.

Note: These data are experimental. Users should take caution using estimates based on subpopulations of the data – sample sizes may be small and the standard errors may be large.**

Total Population 18 Years and Older

Select characteristics	Total*	Household reduced or forwent expenses for basic household necessities, such as medicine or food, in order to pay an energy bill						Total	Percent	Total	Percent
		Almost every month	Some months	1 or two months	Never	Did not report	Did not report				
Total	7,741,821	2,135,348	657,173	800,636	677,539	4,297,218	1,309,254	1,276,804	458,393		
Age		33%						20%			
18 - 24	490,338		38,644	-	175,431	141,043	135,221		31,054		
25 - 39	2,267,692		274,063	313,986	145,428	1,127,722	406,493		172,709		
40 - 54	1,861,471		188,498	251,508	190,216	931,587	299,663		102,447		
55 - 64	1,332,901		105,492	128,107	83,054	776,901	239,346		77,276		
65 and above	1,768,921	240,923	50,477	107,035	83,411	1,299,467	228,531	241,224	74,907		
		16%						16%			
Sex at birth											
Male	3,781,559		299,989	325,321	294,648	2,212,953	648,648		252,899		
Female	3,960,262		357,184	475,315	382,892	2,084,265	660,606		205,494		
Gender											
Cisgender male	1,721,167		93,956	150,189	161,958	1,021,319	293,747		117,097		
Cisgender female	1,802,363		137,605	289,045	159,166	962,281	254,267		74,227		
Transgender	32,733		-	-	-	30,893	1,841		-		
None of these	67,962	21,841	1,850	15,284	4,707	43,686	2,435	25,546	3,620		
		33%						40%			
Did not report	4,117,595		423,763	346,119	351,708	2,239,040	756,966		263,448		
Sexual orientation											
Gay or lesbian	205,117	41,263	9,150	9,393	22,720	112,398	51,455	44,625	12,777		
		27%						29%			
Straight	6,916,922		566,546	733,083	590,946	3,902,733	1,123,615		373,076		
Bisexual	261,479	72,841	33,511	26,324	13,006	129,864	58,774	49,290	25,659		
		36%						25%			
Something else	141,149	61,251	12,830	19,577	28,844	63,348	16,550	#VALUE!	10,411		
		49%						#VALUE!			
I don't know	88,478		12,826	7,476	2,353	51,314	14,509		12,421		
Did not report	128,676		22,310	4,784	19,670	37,561	44,351		24,050		
Lesbian, Gay, Bisexual and Transgender											
Yes	474,297	114,104	42,661	35,717	35,726	248,124	112,069	96,679	38,435		
		32%						27%			
No	3,205,531		182,310	423,060	279,013	1,830,168	490,981		148,572		
Other	137,465		9,885	19,770	5,109	80,914	21,787		16,159		
Did not report	3,924,527		422,317	322,089	357,692	2,138,012	684,417		255,226		
Hispanic origin and Race											
Hispanic or Latino (may be of any race)	411,817	151,099	44,299	81,230	25,570	157,224	103,494	28,202	7,734		
		49%						10%			
White alone, not Hispanic	5,870,413	1,441,571	397,216	497,188	547,167	3,491,132	937,709	875,211	287,737		
		29%						18%			
Black alone, not Hispanic	988,268	372,949	142,007	148,938	82,004	426,448	188,871	249,747	116,247		
		47%						32%			
Asian alone, not Hispanic	173,764	34,676	13,945	7,395	13,336	102,538	36,549	#VALUE!	-		
		25%						#VALUE!			
Two or more races + Other races, not Hispanic	297,559	135,052	59,705	65,885	9,462	119,877	42,630	97,616	46,675		
		53%						39%			
Education											
Less than high school	512,268	233,280	91,749	113,280	28,251	186,764	92,223	146,976	75,593		
		56%						36%			
High school or GED	2,394,911		265,706	274,325	241,940	1,139,028	473,912		180,548		
Some college/associate's degree	2,515,468		230,793	299,404	213,839	1,372,929	398,504		128,566		
Bachelor's degree or higher	2,319,174	376,062	68,925	113,628	193,509	1,598,496	344,616	227,687	73,686		
		19%						12%			
Marital status											
Married	4,095,544		248,937	292,201	292,975	2,612,139	649,294		184,774		

Widowed	400,425		18,866	63,874	28,582	229,954	59,148		24,666
Divorced/separated	1,122,703		138,407	128,526	85,615	565,349	204,806		102,127
Never married	2,075,984		250,963	316,035	270,367	861,470	377,147		146,826
Did not report	47,165		-	-	-	28,306	18,859		-
Household size									
1 person in the household	852,453	260,910	79,859	99,139	81,912	472,704	118,839	182,233	65,849
		36%						25%	
2 people in the household	2,767,149		228,569	178,852	169,944	1,762,166	427,619		181,318
3 people in the household	1,547,217		149,289	209,519	163,567	780,935	243,908		111,988
4 people in the household	1,316,464		93,689	149,340	82,189	675,777	315,469		69,986
5 people in the household	666,168		28,255	102,099	100,260	335,375	100,179		13,030
6 people in the household	265,417		43,756	23,976	4,282	114,030	79,373		9,835
7 or more people in the household	326,952		33,756	37,712	75,385	156,231	23,867		6,386
Presence of children under 18 years old									
Children in household	2,608,552	837,899	260,519	333,343	244,037	1,257,129	513,524	339,062	123,320
		40%						16%	
No children	5,133,269	1,297,450	396,655	467,293	433,502	3,040,089	795,731	937,741	335,072
		30%						22%	
Respondent or household member experienced loss of employment income in last 4 weeks									
Yes	838,003		144,629	159,630	131,950	287,571	114,223		99,799
No	6,713,966		490,234	641,006	543,972	4,001,361	1,037,393		335,450
Did not report	189,852		22,310	-	1,617	8,286	157,638		23,144
Respondent employed in the last 7 days									
Yes	4,507,976		338,902	497,119	415,551	2,596,840	659,564		251,607
No	2,998,779		295,055	297,597	260,371	1,674,570	471,187		183,569
Did not report	235,066		23,216	5,921	1,617	25,808	178,504		23,216
Household income									
Less than \$25,000	998,850	588,517	254,037	215,149	119,331	410,332	-	443,225	161,399
		59%						45%	
\$25,000 - \$34,999	597,734	271,239	150,099	93,498	27,642	315,811	10,683	206,658	91,411
		46%						35%	
\$35,000 - \$49,999	868,360	427,723	89,319	177,473	160,931	439,768	870	187,984	39,337
		49%						22%	
\$50,000 - \$74,999	1,093,592		370,118	68,972	167,413	133,733	723,475		-
		34%							
\$75,000 - \$99,999	764,849		27,868	47,363	84,275	605,344	-		28,773
\$100,000 - \$149,999	967,001		42,866	58,939	91,127	767,555	6,514		23,598
\$150,000 - \$199,999	453,404		2,404	18,143	10,442	422,415	-		9,131
\$200,000 and above	366,068		-	4,445	723	360,900	-		14,790
Did not report	1,631,962		21,608	18,212	49,336	251,619	1,291,187		18,447
Active duty military*									
Serving on active duty	21,885		-	-	11,582	2,103	8,199		-
Serving in Reserve or National Guard	3,932		-	-	-	3,932	-		-
Spouse serving on active duty	915		-	-	-	915	-		-
Spouse serving in Reserve or National Guard	369		-	-	-	369	-		-
No active duty service (self or spouse)	7,587,740		617,827	800,636	665,957	4,286,969	1,216,350		433,115
Did not report	126,981		39,346	-	-	2,930	84,705		25,277
Previous military service*									
No	6,368,039		536,224	696,017	539,915	3,547,305	1,048,577		331,920
Served on active duty	493,345	119,226	23,318	41,282	54,626	325,278	48,840	68,580	35,651
		27%						15%	
Served in the Reserve or National Guard	98,362	#VALUE!	-	14,128	10,054	64,290	9,891	#VALUE!	5,530
		#VALUE!						#VALUE!	
Spouse served on active duty	361,397	77,430	32,927	24,936	19,567	224,866	59,101	#VALUE!	43,215
		26%						#VALUE!	
Spouse served in the Reserve or National Guard	81,789	27,991	9,465	6,780	11,746	44,399	9,399	#VALUE!	-
		39%						#VALUE!	
Did not report	458,071		55,239	19,276	60,140	175,575	147,841		47,606
Difficulty seeing									
No difficulty	5,126,267		310,758	464,937	445,376	3,236,126	669,069		209,528

Some difficulty	1,965,159		282,656	298,730	207,797	1,005,041	170,936		208,430
A lot of difficulty	153,466		32,686	35,664	19,658	47,518	17,941		14,996
Cannot do at all	17,302		13,810	-	-	-	3,493		6,870
Did not report	479,626		17,264	1,305	4,707	8,533	447,816		18,569
Difficulty hearing									
No difficulty	5,954,068		455,047	673,927	586,891	3,560,310	677,894		326,381
Some difficulty	1,101,303		114,545	119,857	75,056	618,981	172,865		91,915
A lot of difficulty	159,868		70,318	4,413	13,705	64,245	7,187		19,640
Cannot do at all	5,380		-	-	1,887	-	3,493		1,887
Did not report	521,202		17,264	2,440	-	53,682	447,816		18,569
Difficulty remembering or concentrating									
No difficulty	4,962,053		345,598	558,023	402,640	3,092,069	563,723		300,174
Some difficulty	1,970,941		256,972	205,060	241,494	1,048,232	219,183		126,522
A lot of difficulty	337,377		54,603	36,248	33,406	138,082	75,039		30,391
Cannot do at all	3,493		-	-	-	-	3,493		-
Did not report	467,957		-	1,305	-	18,835	447,816		1,305
Difficulty walking or climbing stairs									
No difficulty	5,380,016		362,254	581,742	506,262	3,282,211	647,547		276,598
Some difficulty	1,588,433		237,872	192,509	142,428	839,067	176,557		120,503
A lot of difficulty	298,061		57,047	25,080	27,147	161,203	27,584		59,986
Cannot do at all	8,944		-	-	-	4,581	4,363		-
Did not report	466,368		-	1,305	1,701	10,156	453,205		1,305
Difficulty with self-care									
No difficulty	6,580,465		489,291	752,158	568,021	4,004,268	766,728		376,082
Some difficulty	605,143		150,899	46,673	100,824	255,589	51,157		79,241
A lot of difficulty	81,682		4,764	500	8,694	28,828	38,897		1,763
Cannot do at all	4,657		-	-	-	-	4,657		-
Did not report	469,874		12,219	1,305	-	8,533	447,816		1,305
Difficulty understanding or being understood									
No difficulty	6,853,207		525,551	763,072	618,364	4,137,497	808,724		384,799
Some difficulty	368,767		98,507	32,582	56,435	134,046	47,198		57,808
A lot of difficulty	54,588		30,070	3,677	2,740	15,206	2,894		12,543
Cannot do at all	5,429		-	-	-	1,937	3,493		1,937
Did not report	459,830		3,045	1,305	-	8,533	446,946		1,305

* Totals may not sum to 100% as the question allowed for multiple categories to be marked.

** The Census Bureau considers estimated coefficients of variation (standard error divided by the estimate times 100) over 30 percent to indicate potentially serious data quality issues related to sampling error.

Household kept home at a temperature that felt unsafe or unhealthy					Household was unable to pay an energy bill or unable to pay the full bill amount				
Some months	1 or two months	Never	Did not report		Almost every month	Some months	1 or two months	Never	Did not report
462,913	355,498	5,126,950	1,338,067	1,653,911	386,014	734,945	532,952	4,754,646	1,333,264
				26%					
34,270	-	289,794	135,221		6,218	74,773	41,824	232,303	135,221
106,623	169,984	1,410,340	408,035		132,521	352,548	148,327	1,226,280	408,016
132,866	56,886	1,251,028	318,244		164,761	156,425	199,040	1,032,676	308,569
99,332	52,133	854,214	249,946		55,127	75,352	110,575	840,167	251,680
89,822	76,495	1,301,076	226,621	136,421	27,387	75,848	33,186	1,402,722	229,779
				9%					
185,525	146,538	2,522,159	674,438		178,166	277,888	178,148	2,481,071	666,285
277,388	208,960	2,604,791	663,629		207,848	457,057	354,804	2,273,574	666,979
73,791	45,473	1,184,530	300,276		76,770	91,392	68,335	1,181,850	302,821
92,497	129,110	1,252,307	254,222		90,289	242,353	134,400	1,074,682	260,639
5,185	-	25,708	1,841		-	-	-	30,893	1,841
20,076	1,850	38,455	3,960	38,775	1,850	7,777	29,148	26,752	2,435
				59%					
271,364	179,066	2,625,950	777,768		217,106	393,422	301,069	2,440,469	765,529
18,610	13,238	109,038	51,455	29,282	5,519	7,302	16,461	124,380	51,455
				19%					
394,901	323,188	4,676,397	1,149,361		325,520	637,994	509,302	4,298,003	1,146,103
4,559	19,072	151,889	60,300	69,179	21,055	42,152	5,972	133,525	58,774
				34%					
26,513	-	87,675	16,550	#VALUE!	-	22,968	-	101,631	16,550
				#VALUE!					
10,532	-	49,475	16,051		11,609	7,325	1,217	53,818	14,509
7,799	-	52,475	44,351		22,310	17,204	-	43,289	45,873
25,934	32,310	264,023	113,595	98,462	26,575	49,454	22,433	263,767	112,069
				27%					
155,267	167,156	2,237,071	497,466		133,431	283,746	199,534	2,082,394	506,427
18,799	1,850	78,870	21,787		8,903	18,897	15,323	72,554	21,787
262,913	154,183	2,546,986	705,219		217,106	382,848	295,662	2,335,931	692,980
13,407	7,061	267,901	115,713	132,176	26,863	66,645	38,668	176,146	103,494
				43%					
362,899	224,575	4,050,963	944,239	958,788	196,222	385,273	377,293	3,960,161	951,464
				19%					
67,240	66,260	541,452	197,070	419,549	116,568	217,612	85,369	371,457	197,261
				53%					
6,038	19,990	111,187	36,549	22,583	13,945	6,450	2,188	114,632	36,549
				16%					
13,329	37,612	155,447	44,496	120,813	32,415	58,964	29,434	132,250	44,496
				48%					
28,095	43,288	256,954	108,338	173,732	72,721	50,329	50,682	230,197	108,338
				43%					
185,886	107,248	1,435,098	486,131		157,900	304,450	233,661	1,221,729	477,171
161,892	138,002	1,689,569	397,440		109,036	311,672	174,096	1,522,205	398,459
87,040	66,961	1,745,330	346,158	189,364	46,357	68,493	74,514	1,780,515	349,296
				10%					
167,157	138,023	2,942,726	662,864		144,501	245,979	290,391	2,741,325	673,348

28,656	14,792	273,163	59,148		16,319	37,889	53,715	233,354	59,148
74,249	64,593	677,313	204,421		94,401	108,171	74,329	642,907	202,896
192,851	138,090	1,205,442	392,774		130,793	342,906	114,517	1,108,754	379,013
-	-	28,306	18,859		-	-	-	28,306	18,859
67,302	49,082	543,184	127,037	179,455	45,375	86,455	47,625	549,028	123,969
				25%					
174,565	104,760	1,855,728	450,779		107,934	191,149	102,295	1,924,054	441,717
103,231	49,925	1,038,165	243,908		103,447	158,363	161,528	879,971	243,908
40,880	108,092	784,581	312,925		56,378	141,786	114,603	686,706	316,991
33,065	23,886	496,008	100,179		16,292	64,601	58,410	426,685	100,179
-	1,594	174,615	79,373		28,638	13,740	31,518	108,890	82,633
43,869	18,160	234,669	23,867		27,949	78,851	16,973	179,312	23,867
125,576	90,166	1,758,510	510,979	843,295	181,433	406,713	255,149	1,246,952	518,305
				40%					
337,337	265,332	3,368,440	827,088	810,616	204,581	328,232	277,803	3,507,694	814,959
				19%					
54,160	55,291	517,074	111,679		98,288	178,543	113,541	333,408	114,223
408,753	300,207	4,600,806	1,068,750		265,416	556,402	419,411	4,411,335	1,061,403
-	-	9,070	157,638		22,310	-	-	9,903	157,638
270,827	198,623	3,111,728	675,191		176,964	494,237	297,707	2,876,115	662,952
186,166	156,875	1,987,796	484,373		186,739	239,802	235,245	1,845,185	491,808
5,921	-	27,425	178,504		22,310	906	-	33,346	178,504
117,803	164,023	534,839	20,786	490,956	174,689	184,422	131,845	500,854	7,041
				50%					
75,476	39,771	382,303	8,773	243,320	71,365	141,863	30,092	345,641	8,773
				41%					
92,817	55,830	670,432	9,944	290,554	53,325	122,612	114,617	564,602	13,203
				34%					
71,506	47,296	24,916	949,873		-	30,873	158,080	96,968	807,671
44,140	41,740	648,655	1,542		7,150	40,163	59,066	655,313	3,158
50,863	12,697	873,329	6,514		34,583	53,132	51,132	821,640	6,514
15,657	12,038	416,577	-		-	11,399	24,389	417,615	-
1,522	1,650	348,107	-		-	-	-	366,068	-
17,339	2,833	302,835	1,290,508		14,030	23,273	24,843	275,241	1,294,575
9,993	-	3,692	8,199		-	9,993	-	3,692	8,199
-	-	3,932	-		-	-	-	3,932	-
-	-	915	-		-	-	-	915	-
-	-	369	-		-	-	-	369	-
452,920	353,649	5,115,112	1,232,944		349,635	721,984	532,952	4,742,808	1,240,360
-	1,850	2,930	96,924		36,379	2,967	-	2,930	84,705
401,462	322,033	4,263,523	1,049,100		307,311	649,132	457,291	3,897,788	1,056,517
20,245	12,684	377,834	46,930	57,373	12,737	22,928	21,708	389,043	46,930
				13%					
-	3,681	79,260	9,891	#VALUE!	-	15,717	2,340	70,415	9,891
				#VALUE!					
20,634	-	238,447	59,101	64,045	25,562	10,517	27,966	238,251	59,101
				21%					
12,216	2,404	57,770	9,399	#VALUE!	-	17,012	13,570	41,808	9,399
				#VALUE!					
14,290	14,696	203,438	178,041		40,404	27,356	24,285	200,204	165,822
235,620	194,421	3,797,383	689,315		184,867	417,579	307,445	3,530,338	686,038

201,741	142,146	1,234,867	177,977		157,106	269,100	193,928	1,167,048	177,977
25,552	18,932	74,520	19,467		12,967	43,558	31,579	47,422	17,941
-	-	6,940	3,493		13,810	-	-	-	3,493
-	-	13,240	447,816		17,264	4,707	-	9,838	447,816
376,161	282,365	4,276,200	692,962		281,599	591,835	412,827	3,969,061	698,746
80,841	47,470	708,212	172,865		51,070	131,443	96,492	649,434	172,865
5,911	25,663	87,721	20,932		36,081	10,533	23,633	79,276	10,345
-	-	-	3,493		-	-	-	1,887	3,493
-	-	54,816	447,816		17,264	1,134	-	54,987	447,816
245,006	208,407	3,627,904	580,562		193,322	384,376	342,585	3,466,101	575,668
183,565	123,115	1,313,622	224,117		163,401	300,813	178,010	1,104,510	224,207
31,080	23,977	176,891	75,039		29,291	49,756	12,357	170,934	75,039
-	-	-	3,493		-	-	-	-	3,493
3,261	-	8,533	454,857		-	-	-	13,100	454,857
259,237	213,872	3,972,192	658,118		180,330	516,147	379,310	3,639,714	664,515
174,706	117,237	980,170	195,817		153,277	181,818	132,772	936,969	183,597
27,269	24,390	159,850	26,565		52,408	36,979	19,168	161,921	27,584
-	-	4,581	4,363		-	-	-	4,581	4,363
1,701	-	10,156	453,205		-	-	1,701	11,462	453,205
385,992	289,402	4,746,515	782,474		272,032	646,578	506,798	4,366,185	788,872
66,242	64,126	345,395	50,138		98,865	88,367	24,184	342,570	51,157
10,680	1,970	26,507	40,762		2,898	-	1,970	36,052	40,762
-	-	-	4,657		-	-	-	-	4,657
-	-	8,533	460,035		12,219	-	-	9,838	447,816
410,679	308,267	4,927,537	821,926		291,560	681,249	503,257	4,546,273	830,868
46,926	45,080	169,889	49,063		66,647	48,388	28,169	176,500	49,063
5,308	2,152	17,946	16,639		24,762	5,308	1,526	20,098	2,894
-	-	-	3,493		-	-	-	1,937	3,493
-	-	11,578	446,946		3,045	-	-	9,838	446,946

Housing Table 4. Household Energy Use and Spending in the last 12 Months, by Select Characteristics: Detroit-Warren-Dearborn, MI Metro Area

Source: U.S. Census Bureau Household Pulse Survey, Cycle 02.

Note: These data are experimental. Users should take caution using estimates based on subpopulations of the data – sample sizes may be small and the standard errors may be large.**

Total Population 18 Years and Older

Select characteristics	Total*	Household reduced or forwent expenses for basic household necessities, such as medicine or food, in order to pay an energy bill					Almost every month
		Almost every month	Some months	1 or two months	Never	Did not report	
Total	3,355,816	267,567	334,326	314,216	1,805,872	633,834	211,934
Age							
18 - 24	291,698	24,836	-	93,191	72,025	101,645	31,054
25 - 39	948,846	101,478	130,997	64,490	479,210	172,671	54,646
40 - 54	795,211	85,393	90,496	98,757	388,654	131,910	60,901
55 - 64	550,380	30,788	58,801	34,416	290,628	135,746	24,011
65 and above	749,182	25,072	54,032	23,361	554,856	91,862	41,323
Sex at birth							
Male	1,647,698	107,718	140,975	140,222	929,681	329,101	97,183
Female	1,708,118	159,849	193,351	173,994	876,191	304,734	114,751
Gender							
Cisgender male	790,520	39,839	64,559	68,778	450,344	167,000	69,473
Cisgender female	838,870	85,842	119,497	74,744	433,902	124,886	41,956
Transgender	21,072	-	-	-	21,072	-	-
None of these	28,861	-	-	4,707	21,719	2,435	-
Did not report	1,676,491	141,886	150,271	165,986	878,834	339,514	100,505
Sexual orientation							
Gay or lesbian	83,849	9,150	3,595	1,522	67,548	2,034	9,114
Straight	2,944,804	223,630	308,373	259,264	1,623,728	529,809	180,138
Bisexual	170,343	22,196	17,767	9,102	65,338	55,940	9,333
Something else	60,107	982	2,919	28,844	19,822	7,540	-
I don't know	29,395	11,609	151	1,542	8,152	7,941	11,609
Did not report	67,319	-	1,522	13,942	21,285	30,570	1,740
Lesbian, Gay, Bisexual and Transgender							
Yes	254,191	31,346	21,362	10,624	132,885	57,974	18,447
No	1,470,387	87,746	178,549	122,844	822,513	258,735	90,246
Other	36,945	8,035	1,937	5,109	15,655	6,209	7,053
Did not report	1,594,292	140,440	132,478	175,639	834,818	310,916	96,187
Hispanic origin and Race							
Hispanic or Latino (may be of any race)	157,796	22,857	9,126	20,747	48,242	56,823	6,353
White alone, not Hispanic	2,302,410	131,275	189,800	224,683	1,343,799	412,852	117,557
Black alone, not Hispanic	645,605	78,048	102,923	55,929	298,501	110,203	88,024
Asian alone, not Hispanic	130,052	13,945	7,395	7,298	67,471	33,943	-
Two or more races + Other races, not Hispanic	119,952	21,441	25,081	5,558	47,859	20,013	-
Education							
Less than high school	195,883	25,717	25,428	19,177	70,310	55,252	22,570
High school or GED	1,056,191	131,817	142,308	94,230	471,062	216,774	88,876
Some college/associate's degree	1,120,249	89,216	122,163	103,145	585,262	220,464	75,479
Bachelor's degree or higher	983,492	20,817	44,428	97,665	679,238	141,344	25,010
Marital status							
Married	1,635,825	96,769	139,845	86,183	1,013,606	299,423	92,327
Widowed	184,758	5,387	22,312	5,934	117,848	33,276	7,007
Divorced/separated	402,362	32,785	43,596	38,469	208,310	79,202	17,890
Never married	1,110,782	132,626	128,573	183,630	455,593	210,359	94,710
Did not report	22,089	-	-	-	10,514	11,574	-
Household size							
1 person in the household	426,652	33,398	47,036	45,522	245,609	55,087	21,414
2 people in the household	1,092,469	91,514	67,251	63,892	676,755	193,058	108,204
3 people in the household	659,179	54,146	78,497	72,064	332,702	121,771	34,347
4 people in the household	586,024	41,138	71,966	33,126	285,112	154,683	34,100

5 people in the household	278,645	20,909	33,378	43,982	126,371	54,006	1,268
6 people in the household	122,845	4,750	13,740	2,688	70,306	31,362	6,214
7 or more people in the household	190,000	21,712	22,460	52,943	69,019	23,867	6,386
Presence of children under 18 years old							
Children in household	1,150,326	99,416	155,572	105,593	542,435	247,310	52,963
No children	2,205,490	168,151	178,754	208,623	1,263,437	386,524	158,971
Respondent or household member experienced loss of employment income in last 4 weeks							
Yes	423,347	90,729	82,380	44,536	145,662	60,041	83,843
No	2,838,275	176,838	251,947	269,680	1,659,377	480,433	127,258
Did not report	94,194	-	-	-	833	93,361	833
Respondent employed in the last 7 days							
Yes	1,973,709	150,531	225,410	227,519	1,091,498	278,751	115,393
No	1,273,408	116,130	108,916	86,697	708,221	253,443	95,635
Did not report	108,699	906	-	-	6,153	101,640	906
Household income							
Less than \$25,000	386,757	96,958	81,333	62,887	145,579	-	52,308
\$25,000 - \$34,999	298,461	77,013	50,810	26,928	143,710	-	60,698
\$35,000 - \$49,999	298,639	23,302	32,039	69,799	172,629	870	19,159
\$50,000 - \$74,999	471,186	30,207	98,753	33,602	308,623	-	20,442
\$75,000 - \$99,999	373,159	12,560	25,827	49,964	284,809	-	22,854
\$100,000 - \$149,999	388,422	12,749	26,868	36,046	306,245	6,514	13,207
\$150,000 - \$199,999	198,827	-	4,340	6,367	188,120	-	3,365
\$200,000 and above	163,237	-	1,839	723	160,675	-	4,384
Did not report	777,127	14,778	12,517	27,901	95,482	626,450	15,517
Active duty military*							
Serving on active duty	10,302	-	-	-	2,103	8,199	-
Serving in Reserve or National Guard	3,622	-	-	-	3,622	-	-
Spouse serving on active duty	915	-	-	-	915	-	-
Spouse serving in Reserve or National Guard	-	-	-	-	-	-	-
No active duty service (self or spouse)	3,285,687	252,380	334,326	314,216	1,799,232	585,532	208,967
Did not report	55,289	15,186	-	-	-	40,103	2,967
Previous military service*							
No	2,831,739	238,110	295,324	280,697	1,492,029	525,579	175,737
Served on active duty	153,842	1,792	21,352	8,812	109,537	12,349	968
Served in the Reserve or National Guard	26,241	-	1,783	-	22,189	2,269	-
Spouse served on active duty	140,126	2,646	3,905	11,757	100,065	21,753	19,955
Spouse served in the Reserve or National Guard	43,388	7,061	1,613	5,934	24,485	4,295	-
Did not report	207,665	17,958	12,132	12,950	94,615	70,009	15,274
Difficulty seeing							
No difficulty	2,233,189	148,217	212,833	201,876	1,362,280	307,982	97,068
Some difficulty	800,353	101,839	109,525	100,368	409,367	79,254	94,763
A lot of difficulty	79,576	10,641	11,967	7,265	31,762	17,941	13,233
Cannot do at all	10,363	6,870	-	-	-	3,493	6,870
Did not report	232,335	-	-	4,707	2,463	225,165	-
Difficulty hearing							
No difficulty	2,587,131	165,317	288,822	284,914	1,539,211	308,867	139,566
Some difficulty	440,651	74,071	44,370	23,361	206,466	92,384	54,521
A lot of difficulty	48,743	28,179	-	4,055	12,584	3,926	15,959
Cannot do at all	5,380	-	-	1,887	-	3,493	1,887
Did not report	273,911	-	1,134	-	47,612	225,165	-
Difficulty remembering or concentrating							
No difficulty	2,122,711	123,652	239,342	195,824	1,317,787	246,107	138,212
Some difficulty	829,998	133,569	78,919	100,546	421,183	95,781	63,154
A lot of difficulty	171,986	10,346	16,065	17,847	64,439	63,289	10,568
Cannot do at all	3,493	-	-	-	-	3,493	-
Did not report	227,628	-	-	-	2,463	225,165	-

Difficulty walking or climbing stairs							
No difficulty	2,263,319	159,162	217,835	221,832	1,379,518	284,972	136,660
Some difficulty	704,147	86,332	96,618	78,566	346,275	96,355	34,315
A lot of difficulty	144,766	22,072	19,873	13,819	71,411	17,591	40,959
Cannot do at all	8,944	-	-	-	4,581	4,363	-
Did not report	234,639	-	-	-	4,086	230,553	-
Difficulty with self-care							
No difficulty	2,808,512	207,610	303,612	266,292	1,696,552	334,446	185,062
Some difficulty	259,265	44,737	30,714	47,924	105,218	30,671	26,872
A lot of difficulty	43,535	3,000	-	-	1,639	38,897	-
Cannot do at all	4,657	-	-	-	-	4,657	-
Did not report	239,847	12,219	-	-	2,463	225,165	-
Difficulty understanding or being understood							
No difficulty	2,882,924	209,103	318,517	275,165	1,721,443	358,695	187,292
Some difficulty	201,764	33,701	13,658	39,051	70,897	44,457	10,162
A lot of difficulty	38,940	24,762	2,152	-	9,132	2,894	12,543
Cannot do at all	5,429	-	-	-	1,937	3,493	1,937
Did not report	226,758	-	-	-	2,463	224,295	-

* Totals may not sum to 100% as the question allowed for multiple categories to be marked.

** The Census Bureau considers estimated coefficients of variation (standard error divided by the estimate times 100) over 30 percent to indicate potentially serious data quality issues related to sampling error.

Household kept home at a temperature that felt unsafe or unhealthy				Household was unable to pay an energy bill or unable to pay the full bill amount				
Some months	1 or two months	Never	Did not report	Almost every month	Some months	1 or two months	Never	Did not report
203,904	183,107	2,109,954	646,917	155,693	440,039	214,406	1,905,196	640,482
20,462	-	138,537	101,645	6,218	60,966	-	122,869	101,645
33,735	85,844	600,409	174,213	43,604	199,758	69,096	462,195	174,193
76,819	28,480	485,560	143,451	59,076	107,065	64,697	430,597	133,776
34,505	24,828	331,289	135,746	19,409	36,174	59,723	296,069	139,005
38,382	43,955	533,661	91,862	27,387	36,077	20,890	572,967	91,862
86,348	90,763	1,034,628	338,775	80,064	163,210	78,833	994,968	330,623
117,555	92,344	1,075,327	308,141	75,628	276,830	135,573	910,228	309,859
50,014	20,697	485,880	164,456	43,642	63,273	44,483	472,122	167,000
42,384	59,599	568,180	126,751	37,233	163,050	66,213	442,364	130,011
2,419	-	18,653	-	-	-	-	21,072	-
12,299	-	14,128	2,435	-	-	12,299	14,128	2,435
96,787	102,812	1,023,113	353,275	74,818	213,716	91,411	955,510	341,036
15,894	1,522	55,285	2,034	5,519	7,302	13,745	55,249	2,034
173,017	164,917	1,885,383	541,349	129,931	372,002	197,075	1,710,862	534,934
3,357	16,668	85,044	55,940	8,633	39,748	3,586	62,435	55,940
5,109	-	47,458	7,540	-	7,045	-	45,521	7,540
1,989	-	6,313	9,483	11,609	-	-	9,845	7,941
4,538	-	30,471	30,570	-	13,942	-	21,285	32,092
19,251	18,190	140,329	57,974	14,153	47,050	17,331	117,684	57,974
85,451	75,272	961,362	258,056	59,669	182,802	108,355	855,702	263,860
6,947	-	16,735	6,209	7,053	7,045	-	16,637	6,209
92,255	89,644	991,529	324,677	74,818	203,142	88,721	915,174	312,438
2,997	1,245	78,159	69,042	19,923	20,261	3,589	57,200	56,823
164,975	65,324	1,544,246	410,308	56,789	212,593	148,858	1,469,795	414,374
32,198	58,936	354,702	111,745	65,036	155,287	53,209	258,610	113,463
-	19,990	76,119	33,943	13,945	6,450	2,188	73,527	33,943
3,733	37,612	56,727	21,879	-	45,448	6,562	46,063	21,879
15,832	25,742	76,488	55,252	19,465	28,813	20,173	72,180	55,252
80,333	89,128	568,860	228,994	70,990	236,857	71,270	457,040	220,034
61,845	40,273	722,866	219,785	56,574	141,239	95,665	604,442	222,330
45,893	27,964	741,740	142,886	8,664	33,129	27,298	771,534	142,867
68,972	66,968	1,110,681	296,878	58,426	144,208	92,621	1,036,366	304,204
13,198	10,399	120,878	33,276	2,967	18,017	24,376	106,120	33,276
26,740	45,965	232,565	79,202	15,374	53,816	26,552	227,418	79,202
94,994	59,776	635,316	225,986	78,926	223,998	70,857	524,776	212,225
-	-	10,514	11,574	-	-	-	10,514	11,574
29,843	28,256	290,510	56,629	15,658	49,420	31,621	274,866	55,087
41,817	50,714	684,591	207,143	60,082	81,731	67,915	687,817	194,924
53,788	29,836	419,436	121,771	22,862	110,295	47,324	356,927	121,771
16,160	32,256	351,370	152,138	32,649	99,093	19,173	278,904	156,205

25,751	23,886	173,735	54,006	14,529	22,161	22,880	165,069	54,006
-	-	85,268	31,362	3,527	13,740	13,625	57,332	34,621
36,544	18,160	105,043	23,867	6,386	63,599	11,869	84,280	23,867
47,499	75,151	729,947	244,766	49,205	270,316	65,710	513,004	252,092
156,405	107,956	1,380,007	402,151	106,488	169,723	148,696	1,392,192	388,390
38,241	49,581	194,186	57,496	54,147	124,863	41,859	142,437	60,041
165,662	133,526	1,915,768	496,060	101,546	315,176	172,547	1,761,925	487,080
-	-	-	93,361	-	-	-	833	93,361
131,008	86,791	1,346,139	294,378	56,145	311,153	116,645	1,207,627	282,139
72,896	96,316	757,662	250,899	99,548	127,980	97,761	691,416	256,703
-	-	6,153	101,640	-	906	-	6,153	101,640
61,723	72,409	188,098	12,219	61,148	105,124	67,553	152,933	-
38,702	21,618	177,444	-	24,888	97,689	13,508	162,375	-
34,566	37,888	206,157	870	27,959	49,622	31,373	185,555	4,129
16,513	21,293	412,938	-	25,710	106,354	24,843	314,278	-
22,328	16,856	309,578	1,542	1,957	28,193	37,922	305,087	-
17,044	3,733	347,923	6,514	-	32,962	21,663	327,284	6,514
4,258	6,476	184,727	-	-	-	3,796	195,031	-
1,522	-	157,331	-	-	-	-	163,237	-
7,247	2,833	125,759	625,771	14,030	20,095	13,748	99,417	629,838
-	-	2,103	8,199	-	-	-	2,103	8,199
-	-	3,622	-	-	-	-	3,622	-
-	-	915	-	-	-	-	915	-
-	-	-	-	-	-	-	-	-
203,904	183,107	2,103,314	586,395	143,474	437,072	214,406	1,898,556	592,180
-	-	-	52,322	12,219	2,967	-	-	40,103
181,560	166,166	1,783,700	524,577	138,346	401,328	172,087	1,589,617	530,361
6,350	7,715	126,460	12,349	-	9,873	9,589	122,031	12,349
-	-	23,972	2,269	-	1,783	-	22,189	2,269
10,295	-	88,122	21,753	2,486	10,517	19,459	85,911	21,753
10,514	-	28,579	4,295	-	14,608	11,869	12,617	4,295
1,119	9,226	97,952	84,094	14,862	9,647	13,271	98,010	71,875
112,213	126,472	1,576,371	321,064	97,801	265,159	119,172	1,436,428	314,629
89,509	39,673	497,154	79,254	42,863	146,897	88,673	442,666	79,254
2,182	16,962	29,259	17,941	8,158	23,276	6,562	23,639	17,941
-	-	-	3,493	6,870	-	-	-	3,493
-	-	7,170	225,165	-	4,707	-	2,463	225,165
175,503	146,759	1,815,573	309,731	109,762	353,781	167,449	1,640,626	315,515
25,376	36,348	232,021	92,384	22,103	80,774	43,990	201,400	92,384
3,024	-	13,614	16,145	23,829	4,350	2,967	13,671	3,926
-	-	-	3,493	-	-	-	1,887	3,493
-	-	48,746	225,165	-	1,134	-	47,612	225,165
129,019	84,739	1,514,959	255,781	74,464	258,156	116,625	1,422,579	250,888
71,287	74,391	521,977	99,189	72,908	158,185	90,189	411,069	97,647
3,598	23,977	70,555	63,289	8,320	23,699	7,592	69,085	63,289
-	-	-	3,493	-	-	-	-	3,493
-	-	2,463	225,165	-	-	-	2,463	225,165

107,330	104,196	1,626,753	288,380	82,162	308,621	132,026	1,448,892	291,620
82,734	62,021	416,502	108,575	54,338	101,416	69,441	382,597	96,355
13,839	16,889	58,032	15,046	19,193	30,003	12,939	65,040	17,591
-	-	4,581	4,363	-	-	-	4,581	4,363
-	-	4,086	230,553	-	-	-	4,086	230,553
176,945	139,202	1,971,315	335,987	129,027	383,564	191,748	1,764,946	339,227
25,824	43,905	134,537	28,126	13,312	56,475	22,658	136,148	30,671
1,134	-	1,639	40,762	1,134	-	-	1,639	40,762
-	-	-	4,657	-	-	-	-	4,657
-	-	2,463	237,384	12,219	-	-	2,463	225,165
190,794	145,759	2,001,385	357,693	108,557	413,869	191,234	1,805,788	363,477
13,109	35,196	96,974	46,323	22,374	26,170	23,172	83,724	46,323
-	2,152	9,132	15,114	24,762	-	-	11,284	2,894
-	-	-	3,493	-	-	-	1,937	3,493
-	-	2,463	224,295	-	-	-	2,463	224,295

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Lifting the High Energy Burden in America's Largest Cities:

How Energy Efficiency Can Improve Low Income and Underserved Communities

Ariel Dreihobl and Lauren Ross



About the Authors

Ariel Dreihobl joined ACEEE in 2015. She conducts research and analysis on local-level energy efficiency policies and initiatives, with an emphasis on low-income energy efficiency. Ariel earned her master of science in environmental science, policy, and management from a joint-degree program at Central European University, Lund University, and the University of Manchester. She earned her bachelor of arts from Northwestern University.

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Executive Summary



This report provides a snapshot of energy burdens in cities across the US. We focus on the high home energy burdens faced by select groups in major metropolitan areas.¹ Years of analysis by the firm of Fisher Sheehan & Colton determined that low-income households pay proportionally more than the average household for energy costs.² Our analysis builds on this research as we take a closer look at energy burden in specific household groups. In the first half of this report, we analyze data from the US Census Bureau's 2011 and 2013 American Housing Survey to determine energy burden values for 48 of the largest US cities and specific households within each city. In the second half of the report, we discuss strategies for alleviating high energy burdens, with a focus on policies and programs to increase the impact of energy efficiency initiatives in these communities.

Families who face higher energy burdens experience many negative long-term effects on their health and well-being. These families are at greater risk for respiratory diseases and increased stress, and they can experience increased economic hardship and difficulty in moving out of poverty. Our research determined that the overwhelming majority of single-family and multifamily low-income households (those

with income at or below 80% of area median income), minority households, low-income households residing in multifamily buildings, and renting households experienced higher energy burdens than the average household in the same city.³ For example, the median US energy burden across all cities in our sample was 3.5%. The median low-income household's energy burden was more than twice as high at 7.2%, and

three times greater than higher income households (2.3%). Overall, low-income households experienced the highest median energy burden (7.2%), followed by African-American households (5.4%), low-income households living in multifamily buildings (5.0%), Latino households (4.1%), and renting households (4.0%).⁴ We also examined the results by region and found that these groups faced the highest average energy burdens in the Southeast and Midwest regions.

Research Results: US Energy Burden Landscape

The efficiency of housing stock is an important factor that influences a household's energy burden. Low-income households, renters, African-American households, and Latino households paid more for utilities per square foot than the average household, indicating that they reside in less efficient housing (see table ES1).

When we compared each group's expenditures on energy per square foot with the median household expenditure, we were able to determine the extent to which home inefficiency contributed to energy burden as compared with lower incomes. We found that for low-income households and for multifamily low-income households, bringing housing stock up to the efficiency of the median household would eliminate 35% of excess energy burden, reducing energy burden from 7.2% to 5.9%. For African-American, Latino, and renting households, 42%, 68%, and 97% of their excess energy burdens, respectively, could be eliminated by raising household efficiency to the median.

By examining these specific groups within cities, we found that many households experienced energy burdens that greatly exceeded both the overall median of 3.5% and their city medians. Median energy burdens were as high as 13% for some groups.

TABLE ES1. Median income, utility bill, energy burden, and unit size for households based on income type, building type, building ownership, and household race for groups across all metro areas

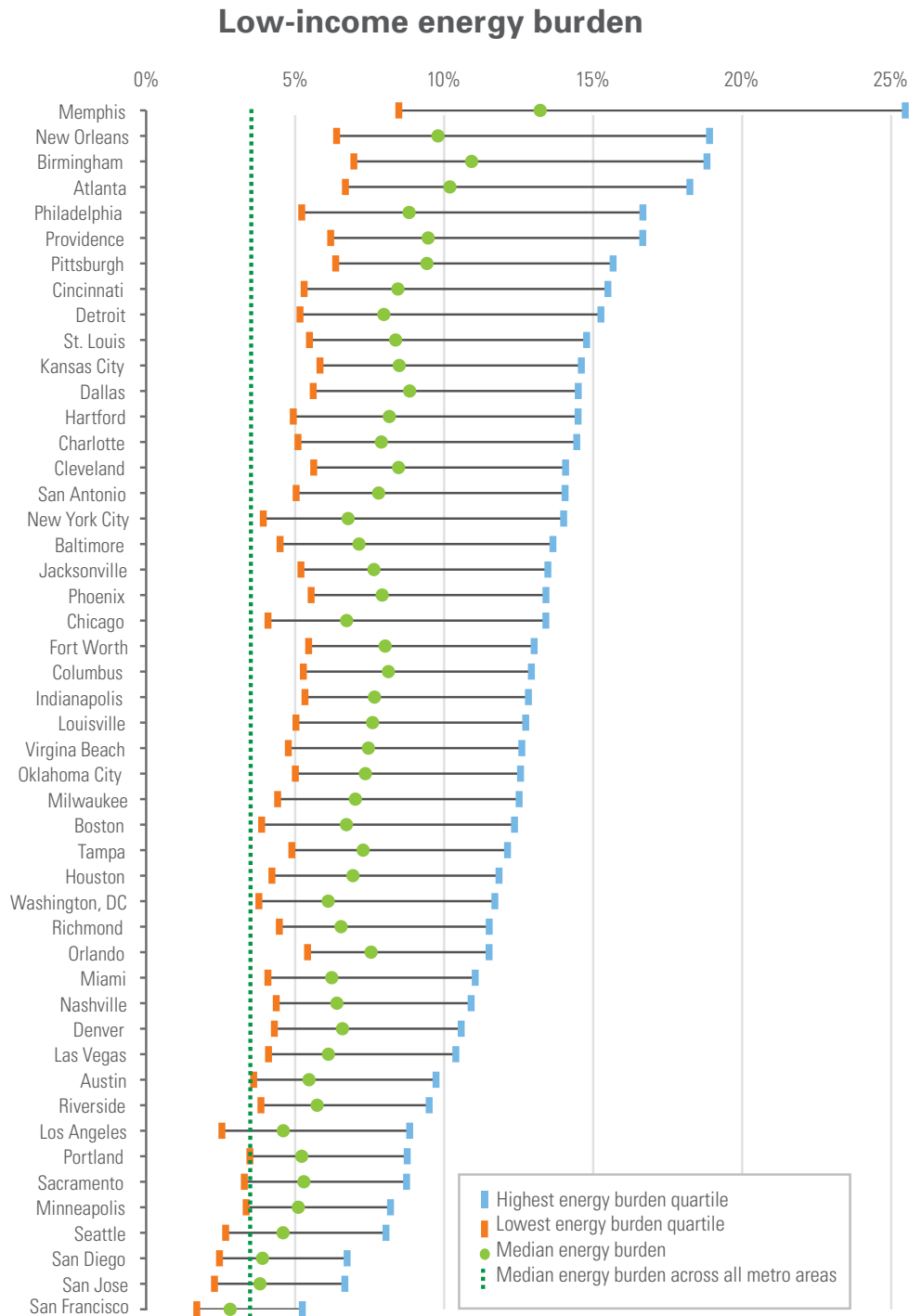
	Household type	Median annual income	Median size of unit (square feet)	Median annual utility spending	Median annual utility costs per square foot	Median energy burden ¹
Income type	Low-income ² (≤80% AMI) ³	\$24,998	1,200	\$1,692	\$1.41	7.2%
	Non-low-income	\$90,000	1,800	\$2,112	\$1.17	2.3%
	Low-income multifamily (≤80% AMI)	\$21,996	800	\$1,032	\$1.29	5.0%
	Non-low-income multifamily	\$71,982	950	\$1,104	\$1.16	1.5%
Building ownership	Renters	\$34,972	1,000	\$1,404	\$1.40	4.0%
	Owners	\$68,000	1,850	\$2,172	\$1.17	3.3%
Head of household race	White	\$58,000	1,600	\$1,956	\$1.22	3.3%
	African-American	\$34,494	1,290	\$1,920	\$1.49	5.4%
	Latino	\$39,994	1,200	\$1,704	\$1.42	4.1%
All households	N/A	\$53,988	1,573	\$1,932	\$1.23	3.5%

¹ Energy burden is the percentage of household income that is spent on energy bills. To calculate median energy burden, we calculated energy burden for all households and then took the median. This value differs from the median energy burden that is calculated using median annual utility spending and income.

² Low-income includes both single- and multifamily households. ³ Area median income (AMI) is the median dollar amount that divides the population into two equal parts.

Source: American Housing Survey (Census Bureau 2011 and 2013a).

FIGURE ES1. Low-income ($\leq 80\%$ AMI) household energy burden for the median, highest energy burden quartile, and lowest energy burden quartile households. The orange bars represent the beginning of the quartile of low-income households with the lowest energy burden. The blue bars represent the beginning of the quartile of low-income households with the highest energy burden. These data include both single- and multifamily low-income households.



For low-income households, we found that energy burden varied substantially. Figure ES1 presents energy burden data for low-income households in each city at the lowest, median, and highest energy burden quartiles. In 17 cities—which is more than one-third of the cities studied—a quarter of low-income households experienced an energy burden greater than 14%, substantially higher than the 3.5% average for all households.

Strategies for Improving Energy Efficiency in Low-Income Communities

Reducing high energy burden on low-income households is a well-established policy objective at the federal, state, and local levels. To help meet this objective, many state utility regulators require that utilities provide bill assistance programs that complement federal programs, such as the Weatherization Assistance Program (WAP) and the Low Income Home Energy Assistance Program (LIHEAP). In addition, many utility regulators require utilities with energy efficiency programs to target low-income customers.

Participants in energy efficiency programs, utilities, and whole communities experience multiple benefits from increased investments in energy efficiency. These benefits include improved health and safety, reduced risk of utility rate increases, reduced costs associated with arrearages and shutoffs, investment in the local economy, and local job creation, among others.⁵ While energy efficiency programs provide benefits beyond energy savings, we find they are an underutilized strategy that could complement bill assistance and weatherization programs to reduce high energy burdens in low-income communities.

We propose the following strategies for improving energy efficiency in low-income communities: (1) Improve and expand low-income utility programs. (2) Collect, track, and report demographic data on program participation. (3) Strengthen policy levers and leverage existing programs. (4) Utilize the Clean Power Plan to prioritize investment in low-income energy efficiency.

Improve and Expand Low-Income Utility Programs

To increase program impact in low-income single- and multifamily housing, energy efficiency program managers should design programs to meet the needs

While energy efficiency programs provide benefits beyond energy savings, we find they are an underutilized strategy that could complement bill assistance and weatherization programs to reduce high energy burdens in low-income communities.

of diverse low-income communities, include a range of eligible measures and services, coordinate delivery with other services, align and add on to existing weatherization efforts, address health and safety, and incorporate energy efficiency education into program design.⁶

Low-income programs should also target multifamily customers, who are often underserved by energy efficiency programs. More than two-thirds of the multifamily rental market consists of households that have an annual household income of less than \$50,000 (NMHC 2015). Yet residential energy efficiency programs administered by states and utilities have historically focused on single-family, owner-occupied housing. Efficiency measures are far less likely to be installed in multifamily rentals than in any other type of housing, leaving significant energy savings unrealized. Examples of best practices in multifamily programs include integrating direct installation and rebate programs, streamlining rebates and incentives, offering multiple pathways to participation, and incorporating on-bill repayment or low-cost financing, among others.⁷

Access to up-front capital is one of the many barriers to energy efficiency for low-income single- and multifamily households and property owners. Financing programs—provided by several utilities and public and community-based entities—can serve as a complement to energy efficiency programs for low-income customers. With strong consumer protections in place, energy efficiency loans can be beneficial for some households and allow the financing of cost-saving measures. Financing options can also benefit multifamily building owners who lack the up-front capital to invest in energy efficiency retrofits.

Collect, Track, and Report Demographic Data on Program Participation

By collecting and making demographic data on program participation public, utilities can assess the extent to which their programs are serving different segments of the population, especially those customers known to experience high energy burdens. Demographic information can inform program design and marketing and outreach strategies. Examples of demographic data that should be incorporated into program evaluation include income level, renter versus owner, multifamily versus single family, and race/ethnicity.

Strengthen Policy Levers and Leverage Existing Programs

Utility regulators and boards of publicly owned utilities should aid utilities in developing, promoting, and executing strong low-income programs by approving and setting goals and guidelines for spending, savings, cost recovery, and cost-effectiveness testing. Additionally, state and local governments can set policy directives that support low-income energy efficiency, including disclosure and benchmarking policies for multifamily buildings, workforce development initiatives, state-level requirements for utility-delivered energy efficiency that include low-income goals, and other special efforts. Some public utility commissions (PUCs) also set low-income energy savings goals and spending requirements in order to increase investment in low-income energy efficiency. Many community-based organizations, city governments, and local utilities can petition PUCs to advance stronger low-income savings goals.

Few utilities include the nonenergy benefits of energy efficiency in their cost-benefit testing.⁸ Both PUCs and

local governments can encourage or require that cost-effectiveness testing take into account the multiple benefits of low-income energy efficiency programs.

Utilize the Clean Power Plan to Prioritize Investment in Low-Income Energy Efficiency

The Clean Power Plan—the first rulemaking to set limits on carbon pollution from power plants—offers another incentive for investment in low-income energy efficiency. States have several choices in developing their compliance plans, and they have the opportunity to prioritize low-income energy efficiency programs in this process. States can also opt into the Clean Energy Incentive Program, which offers early credit for energy efficiency projects in low-income communities during the two years before the start of the compliance period. These new regulations can make investment in low-income energy efficiency more attractive at the state and local levels.

Conclusion

We determined that low-income households and other groups experience higher energy burdens than households on average. Low-income families often live in less efficient housing and pay more per square foot on energy costs. Current utility-led energy efficiency programs could better complement bill assistance and weatherization programs to reduce high energy burdens in low-income communities. Our research identified several strategies to ramp up energy efficiency in these communities. While these represent important steps, we still have much work to do to increase energy affordability among vulnerable communities across the country.

-
- 1 Energy burden refers to the percentage of gross household income spent on energy bills.
 - 2 For more information on Fisher Sheehan & Colton's previous work on the Home Energy Affordability Gap, see www.homeenergyaffordabilitygap.com.
 - 3 Area median income (AMI) is the median dollar amount that divides the population into two equal parts. HUD uses AMI to determine eligibility for low-income programs based on metropolitan area and household size.
 - 4 Single-family low-income households experienced the highest average energy burden of 7.8%. We did not specifically analyze these households in this study.
 - 5 For more information, see C. Russell et al., *Recognizing the Value of Energy Efficiency's Multiple Benefits* (Washington, DC: ACEEE, 2015).
 - 6 For a more comprehensive discussion on successful low-income utility programs, see R. Cluett, J. Amann, and S. Ou, *Building Better Energy Efficiency Programs for Low-Income Households* (Washington, DC: ACEEE, 2016).
 - 7 For a more comprehensive discussion of best practices in multifamily energy efficiency programs, see K. Johnson, *Apartment Hunters: Programs Searching for Energy Savings in Multifamily Buildings* (Washington, DC: ACEEE, 2013).
 - 8 See M. Kushler, S. Nowak, and P. Witte, *A National Survey of State Policies and Practices for Evaluation of Ratepayer Funded Energy Efficiency Programs* (Washington, DC: ACEEE, 2012).

Introduction



This report analyzes energy affordability in cities across the United States, focusing on the high home energy burdens faced by select groups in major metropolitan areas. As defined in this study, a household's energy burden is its total annual utility spending (electric, gas, and/or other heating fuel) as a percentage of total annual gross household income. We focus on households in select cities due to the high concentration of poverty in cities, as well as the availability of city-level data.⁹ However households in rural areas also suffer from high energy burdens (McCormick 2015). Our focus on cities does not imply that high energy burdens are not a serious issue in rural communities.

Years of analyzing home energy burdens by the firm of Fisher Sheehan & Colton have determined that low-income households pay proportionally more than the average household for energy (Fisher Sheehan & Colton 2013). Our analysis builds on this research as we look more closely at the energy burden of specific household groups. For low-income families, the majority of household income goes toward rent, transportation, and energy, in that order (CNT 2016).¹⁰ In this study, we measure only home energy burden,

which includes all spending on a home's energy utility bills. Spending on rent, water, and transportation is outside the scope of this analysis.

Annual energy bills may be affordable for one family but not for another due to differences in income. For example, a low-income family and middle-income family may pay the same \$1,800 per year on utilities (\$150 monthly average), but for the low-income family, this will be a larger burden on the household.

The data we examine show that the median energy burden for low-income households is more than two times that of the median household (7.2% and 3.5%, respectively), and three times greater than higher income households (2.3%).

This utility bill may represent 8% of annual household income for the low-income family and only 3% for the middle-income family, indicating that the low-income household faces a disproportionate energy burden. The data we examine show that the median energy burden for low-income households is more than two times that of the median household (7.2% and 3.5%, respectively), and three times greater than higher income households (2.3%). Low-income households also pay more per square foot for energy than the average household. These families experience higher



energy burdens not only because of lower incomes but also because of inefficiencies in the home. This causes families to face trade-offs between energy and other basic necessities, such as food and medical care.

In the first half of this report, our analysis uses data from the US Census Bureau's *American Housing Survey* (AHS), a national sample of households, to systematically measure energy burdens in metro areas. In the second half of the report, we highlight several policies and programs that can reduce the high energy burden of many households, with a particular focus on programs to improve the energy efficiency of low-income housing. We conclude with an overview of recommended strategies for increasing investments in low-income energy efficiency.

While high energy costs are an important social and economic issue, few have systematically analyzed how energy burdens vary across the country and among specific groups. By developing a clearer understanding of the intersection of energy costs and household demographics, stakeholders can better target investments in energy efficiency to create more economically viable and healthy communities.

-
- 9 According to the Brookings Institute's 2013 study, poverty is concentrated in metropolitan areas. Of the families at or below the federal poverty level, 7.3 million live in rural areas as compared to 13.4 million in large cities and a growing 16.4 million in suburbs (Ross 2013).
- 10 See the Center for Neighborhood Technology's Housing + Transportation Index for more information on housing and transportation affordability: www.cnt.org/tools/housing-and-transportation-affordability-index.

Causes and Effects of High Home Energy Burden

What Is a High Home Energy Burden, and Why Is It Important?

There is no widely accepted value or threshold that establishes whether a household faces a high or unaffordable energy burden. Some researchers suggest home energy bills are unaffordable when they represent more than 6% of a household's annual gross income; others suggest a threshold of at least 10 or 11% of a household's annual gross income (Fisher Sheehan & Colton 2015; Heindl 2015; Hernández and Bird 2010).¹¹ Fisher Sheehan & Colton recommends using an affordability standard of 6% of gross household income based on the idea that a household can afford to spend about 30% of income on shelter costs and that about 20% of shelter costs are used for energy bills. Meanwhile, the Applied Public Policy Research Institute for Study and Evaluation (APPRISE) uses a model that identifies a severe shelter burden as 50% or more of income, and energy costs as about 22% of shelter costs.¹² Using this approach, APPRISE

suggests that analysts use 11% of income as an indicator of high energy burden (APPRISE 2007). Other researchers and policymakers use the area median energy burden as the threshold for affordable energy. For example, the Nevada Percentage of Income program indicates that low-income home energy burden should be no higher than that of a median-income household (Nevada 2013). Others suggest that high energy burden should be defined as twice the median (Liddell et al. 2012; Moor 2012). When we discuss high energy burden in this report, we refer to households with an energy burden greater than the city's median energy burden.

As in the case of housing and transportation costs, low-income households spend a greater proportion of their income on energy costs compared with the average household.

The families who are the worst off—such as those with extremely low incomes or who face sudden economic



hardship—often suffer from high rates of arrearages and potential utility shutoffs due to unpaid energy bills. These families often live in older, less efficient housing stock, which means that their homes require more energy for heating and cooling than newer, more efficient housing (Penney and Kloer 2015). Due to lack of savings, disposable income, and access to credit, low-income households also have fewer choices in regard to housing options, with many low-income families living in units with structural deficiencies that can make energy retrofits not viable. These families also experience greater barriers to upgrading housing stock with traditional efficiency measures, especially in multifamily buildings where the majority of low-income residents are renters (EPC 2013a).

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physical, economic, policy, and behavioral factors that cause high energy burden.

Causes of High Home Energy Burden

Numerous factors contribute to a high household energy burden. Commonly reported causes of high utility expenses are inefficiencies in housing, such as poor insulation or air leaks; inefficient heating systems and appliances; lack of control over systems and appliances (e.g., in rental households); lack of access to or information about relevant energy efficiency programs; and lack of knowledge about energy conservation measures. High energy burden can also be caused by income reductions, such as loss of employment or support, or an increase in utility bills, such as with additional children or adult household members. In table 1, we list a range of possible

Even though they spend a larger proportion of their income on energy than the average home, low-income households typically spend less on energy overall. According to the US Energy Information Administration's 2009 *Residential Energy Consumption Survey*, low-income households spend on average \$1,690 annually on energy bills, while the average non-low-income household spends \$2,134 per year (EIA 2009).¹³ However low-income utility bills are lower not because low-income households are more efficient, but often because they live in smaller spaces.

At the same time, low-income households spend much more per square foot on utilities, with an average cost of \$1.23 per square foot for low-income households

TABLE 1. Drivers of household energy burden

Type of driver	Examples
Physical	Inefficient and/or poorly maintained HVAC systems
	Heating system and fuel type
	Poor insulation, leaky roofs, and inadequate air sealing
	Inefficient large-scale appliances (e.g., refrigerators, dishwashers) and lighting sources
	Weather extremes that raise the need for heating and cooling
Economic	Chronic economic hardship due to persistent low income (see text box "Income Inequality and Energy Affordability")
	Sudden economic hardship (e.g., severe health event or unemployment)
	Inability or difficulty affording the up-front costs of energy efficiency investments
Policy	Insufficient or inaccessible policies and programs for bill assistance, weatherization, and energy efficiency for low-income households
	Certain utility rate design practices, such as high customer fixed charges, that limit the ability of customers to respond to high bills through energy efficiency or conservation
Behavioral	Lack of access to information about bill assistance or energy efficiency programs
	Lack of knowledge about energy conservation measures
	Increased energy use due to age or disability

versus \$0.98 for non-low-income households (EIA 2009). The higher energy cost per square foot in low-income households appears to be, at least in part, a function of energy use, household/appliance efficiency, and unit size. Low-income households make up the majority of multifamily rentals, and families who rent tend to use more energy on average than owner-occupied homes, due in part to the difficulties renters face in regard to energy efficiency investments (Carliner 2013). In addition, the structure and appliances are less efficient in low-income housing (Penney and Kloer 2015). For example, low-income households are more likely to have older and less efficient appliances such as refrigerators and washing machines (EIA 2013). Finally, energy consumption is typically spread over a smaller area in low-income households, which are on average smaller than the average home (Census Bureau 2013a).

Investing in energy efficiency upgrades is often more challenging for low-income households than for higher-income households. For renters, of which the majority are low-income, landlords who do not pay for utilities may not be motivated to invest in efficiency upgrades, and renters may not want to invest, unsure if their

tenure will be sufficient to recoup the investment. In many cases, low-income home and building owners are not able to afford the up-front investment needed to upgrade housing stock and equipment. The type of heating system installed in a building will also influence energy burden, as certain heating technologies are more expensive than others. Later in this report, we discuss strategies for overcoming the up-front barriers to energy efficiency investments for low-income households.

Customers who have difficulty paying their bills may ultimately contribute to additional utility costs that can increase utility bills for all customers. For example, the utility's costs for covering arrearages, bill payment accommodations, and shutoffs are distributed to all ratepayers. Therefore, customers' inability to meet monthly utility payments may lead to higher costs for the utility, which can lead to even higher home energy burdens for all households.

A recent trend toward raising fixed monthly charges on customer utility bills also threatens energy affordability, especially for low-income customers (Kind 2015). Fixed charges are generally applied to all bills equally, or based on peak demand, and are not related to the volume of energy usage. Shifting costs to fixed charges and away from the amount of energy use itself acts as a disincentive for energy efficiency and reduces the ability of the customer to save money by conserving energy (Whited, Woolf, and Daniel 2016). Increases in energy bills due to higher fixed charges pose a real threat to already overburdened households, negating their efforts to avoid high energy bills by reducing consumption. Strategies aimed at improving energy affordability must also address the issue of rising fixed charges and their impacts on low-income customers.

Therefore, customers' inability to meet monthly utility payments may lead to higher costs for the utility, which can lead to even higher home energy burdens for all households.

INCOME INEQUALITY AND ENERGY AFFORDABILITY

If income does not increase for all households on par with changes in energy costs, household energy burden for low-income and disadvantaged households will increase in future years. In the largest US cities, income inequality continues to rise and consistently remains higher than the national average (Stone et al. 2015). Between 1979 and 2007, the average income of the bottom 99% of households grew by 18.9%, while the average income of the top 1% of households grew by 200.5% (Sommeiller and Price 2015; Desilver 2015). According to a 2016 Brookings report, declining incomes are an influential factor in present-day inequality, as most households in cities experience growing income inequality between the top 5% and bottom 20% of households (Berube and Holmes 2015). Slow income growth—or even real income decline at the lowest levels—can lead to more extensive economic hardship and unaffordable energy costs. From 2004 to 2014, average US residential electricity prices increased from 9 cents/kWh to 12.5 cents/kWh, an increase of 39% (EIA 2016a). In contrast, average adjusted income grew from \$29,900 in 2004 to \$30,180 in 2014, an increase of 0.9% (Census Bureau 2014). If energy prices continue to increase more rapidly than income, energy burden will continue to grow for vulnerable households.

Families suffering from high energy burdens also tend to experience stress from living in constant fear of losing necessary electricity and gas service due to inability to pay their bills.

Effects of High Energy Burden

Addressing energy affordability can help to break the cycle of poverty and improve economic development, educational achievement, and public health. High energy burden can cause very real mental and physical health problems for household members due to thermal discomfort, inadequate lighting, unsafe housing conditions, and constant financial and social stress. Individuals who experience high energy burdens may cut back on necessary energy use and inadequately heat, cool, and light their homes, which can result in many negative health consequences.

Studies have found that living in homes that are not properly heated or cooled increases cases of asthma, respiratory problems, heart disease, arthritis, and rheumatism (Heyman 2011; Hernández and Bird 2010; Liddell and Morris 2010; Wright 2004). Children and the elderly are more susceptible to these health impacts. Families suffering from high energy burdens also tend to experience stress from living in constant fear of losing necessary electricity and gas service due to inability to pay their bills.

For many low-income families, this compounds with other stresses, such as difficulty accessing health care, fear of losing their housing, and living in potentially unsafe buildings and neighborhoods. These constant stresses cause serious health problems.

Researchers have also found that high energy burdens affect mental health by creating more stressful environments, increasing social isolation, and negatively impacting educational achievement and emotional resiliency (Li et al. 2014; Dear and McMichael 2011; Liddell and Morris 2010). Families that have trouble paying their energy bills may sacrifice nutrition, medicine, and other necessities in order to avoid shutoffs. These effects are especially detrimental to the physical and mental development of children. Living in underheated homes puts adolescents at double

the risk of respiratory problems and five times the risk of mental health problems (Dear and McMichael 2011). Families may also cope with high energy burdens by heating fewer rooms in their home and reducing lighting use (Bruner Spitzer, and Christanell 2012). These stresses can hinder the ability of adolescents to study and complete school assignments, which negatively affects their academic success.

High energy burdens can also cause societal problems extending well beyond the household. For example, 5.5% of low-income customers in California experienced disconnections for nonpayment in 2011 as compared with 2.9% of non-low-income customers. Half of the disconnected households owed less than \$315, and 6% of those disconnected did not reconnect within the year. Because of the disconnections, some of these families improvised hazardous methods to light and heat their homes (Watts-Zagha 2011). Additionally, researchers conducted studies in northern Kentucky, St. Paul, and Philadelphia and found utility shutoffs to be one of the primary factors that led to homelessness (Vick and Norton 2008).

Ultimately, the drivers and effects of high energy burden create a negative feedback loop that can become a trap that is hard to escape. Various factors associated with low income contribute to a high energy burden. In turn, higher utility bills require more of a family's income and make them more likely to remain in poverty.

The troubling reality is that many households resort to high-cost payday lending in order to pay their utility bills, which can further exacerbate the cycle of poverty. A 2012 study found that paying utility bills was the most common reason why individuals took out a payday loan (Levy and Sledge 2012). These loans are small, short-term loans with high interest rates that can make repayment difficult and costly. By addressing energy affordability, policymakers can help to break the cycle of poverty and increase economic development, educational achievement, and public health.

- 11 For more information on defining the energy affordability gap, see Fisher Sheehan & Colton's Home Energy Affordability Gap research at www.homeenergyaffordabilitygap.com. They provide a model that calculates the monetary gap between actual and affordable home energy bills at the county level for segments of the low-income population. Their model includes factors left out of this research, such as household size, fuel mix, and heating and cooling degree days.
- 12 In this context, shelter costs include all expenses relating to housing, such as rent or mortgage payments, condominium fees, utilities, and property taxes.
- 13 In 2009, the US Energy Information Administration's Residential Energy Consumption Survey defined "low-income" as less than or equal to 150% of the federal poverty line (FPL). This survey compiles data from a household survey and energy supplier survey and uses estimates of consumption and expenditures.

The US Home Energy Burden Landscape



We took a snapshot of energy burdens across the largest US metropolitan areas, with a focus on select groups. These data have helped us understand the disproportionate impact of energy burden on vulnerable households and the extent to which this experience varies regionally.

Methodology

Research shows that low-income households, especially renters and minority households, face disproportionate energy cost burdens (Hernández 2015). As part of this analysis, we focus on the energy burdens experienced by four groups of households:

- *Low-income households*: those who report an annual gross household income at or below 80% of the area median income, including both single- and multifamily households¹⁴
- *Low-income multifamily households*: those who report an annual gross household income at or below 80% of the area median income and reside in a building with five or more units

- *Minority households*: African-American and Latino families¹⁵
- *Renting households*

We analyzed data from the US Census Bureau and US Department of Housing and Urban Development's (HUD) *American Housing Survey* (AHS) in 2011 and 2013. This survey samples households across the US to gather information on housing stock characteristics, housing and energy costs, occupant characteristics, and other related information (Census Bureau 2011 and 2013a). The survey is conducted every two years in 25 to 30 metro areas; the 2011 and 2013 surveys contain the most recent city data available. The survey's unit of analysis is the household, and interviewees self-report

TABLE 2. Metropolitan statistical areas (MSAs) included in analysis, by region

Northeast	Southeast	Midwest	South Central	Southwest	Northwest	California
Baltimore	Atlanta	Chicago	Austin	Denver	Portland	Los Angeles
Boston	Birmingham	Cincinnati	Dallas	Las Vegas	Seattle	Riverside
Hartford	Charlotte	Cleveland	Fort Worth	Phoenix		Sacramento
New York City	Jacksonville	Columbus	Houston			San Diego
Philadelphia	Louisville	Detroit	Oklahoma City			San Francisco
Pittsburgh	Memphis	Indianapolis	San Antonio			San Jose
Providence	Miami	Kansas City				
Washington, DC	Nashville	Milwaukee				
	New Orleans	Minneapolis				
	Orlando	St. Louis				
	Richmond					
	Tampa					
	Virginia Beach					

all collected information. For this study, we analyzed individual household-level data to measure energy burden in 48 of the largest US metropolitan statistical areas (MSAs), as detailed in table 2.¹⁶

Data Limitations

We experienced a few limitations in our analysis that should be considered when examining the results. While city samples are representative, these data represent only a snapshot in time (2011 and 2013). Therefore, the results may not reflect future energy burdens. Volatile gas or oil prices, stagnant wages, and rising electricity prices in past and future years could also significantly impact home energy burden. We did not adjust energy bills to reflect the difference in energy prices between 2011 and 2013 (EIA 2016b).

These data are also self-reported. Every household in the sample provided self-reported estimates of average monthly electricity and heating fuel bills, as well as estimated household income and household size. Even so, our findings are comparable to EIA's 2009 *Residential Energy Consumption Survey* (EIA 2009). EIA found that the average household spent \$2,134 and low-income household spent \$1,690 annually on energy bills, which is similar to our findings of \$1,932 and \$1,692 median annual bills for the average household and low-income household.

We also limited our sample to include only those households that reported positive income, paid their electricity bill directly, and also directly paid for their main heating fuel (electricity, gas, fuel oil, wood, coal, kerosene, or other).¹⁷ Due to a lack of data necessary to calculate energy burden, our analysis necessarily excludes two categories of low-income homes that often have a high energy burden: households without any reported income and households in master-metered apartment buildings where energy costs are paid by the landlord and incorporated into monthly rent. Before we limited the sample sizes, the average city sample size was 4,190 households. This was reduced to 2,700 households after controlling for the above factors.

Measuring Home Energy Burden

We calculated energy burden as follows:

$$\text{HOME ENERGY BURDEN} = \frac{\text{TOTAL ENERGY UTILITY SPENDING}^{18}}{\text{TOTAL GROSS HOUSEHOLD INCOME}}$$

We first determined the energy burden for each household in our data set, and then calculated the median burden for each of the four household groups in each metro area (see Appendix B).¹⁹

We also examined the households at the highest energy burden quartile in each group. (Simply put, 25% of households have an energy burden equal to or greater than the highest energy burden quartile value.) Appendix C shows the highest energy burden quartile value alongside the median. This additional analysis of the highest quartile gives a better sense of the burden placed on the most vulnerable households in each metro area, without the median burden masking the extremes.

Because different cities have different median energy burdens, comparing vulnerable groups between cities becomes difficult and potentially misleading. To provide a way to compare groups between cities, we created a metric that measures the proportion of each group that experiences an energy burden greater than or equal to twice the metropolitan area's median energy burden. We report these results in Appendix D.

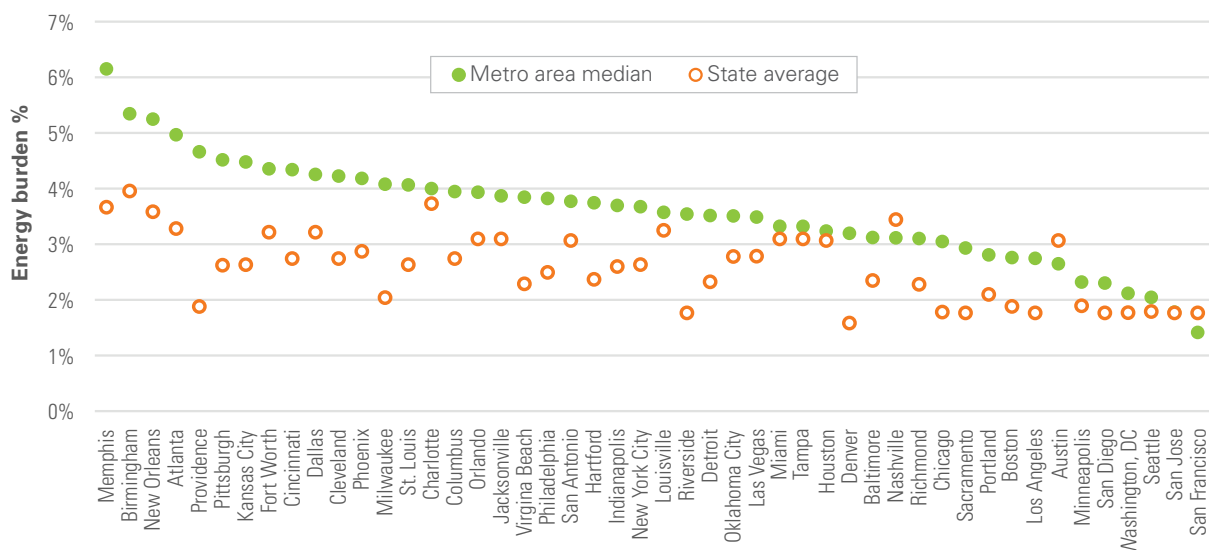


Results: Energy Burdens in US Cities

Figure 1 compares the median energy burden in each metro area with the average for its state. Because we could not calculate state energy burdens using the AHS data set, we used EIA and US Census Bureau data to make these calculations. Most cities have higher energy burdens than the state average.²⁰ The five cities

with the greatest difference between the city and state energy burden were Providence, Memphis, Milwaukee, Pittsburgh, and Kansas City. In these cities, the median metro-area energy burden ranged from 1.9 to 2.8 percentage points greater than the overall burden for the state.

FIGURE 1. Median energy burden for metro area and average energy burden for state households. Metro areas are ranked by their median energy burden. We used American Housing Survey (AHS) data from 2011 and 2013 to calculate the median energy burden for the metro areas (Census Bureau 2011 and 2013a). We also used data from the 2011 and 2013 US Energy Information Administration (Annual Electric Power Industry Report, EIA-861) and average historical income from 2011 and 2013 (Census Bureau 2013b) to calculate the average energy burden for the states.



Metro areas also varied by their median energy burden, ranging from more than 6% to less than 1.5%. The cities with the highest median energy burdens were Memphis (6.2%), Birmingham (5.3%), New Orleans (5.3%), Atlanta (5.0%), and Providence (4.7%). These metro areas—and others with higher median energy burdens—differ from one another in terms of typical energy costs. Overall, metro areas in the Southeast and Midwest regions faced the highest median energy burdens.

It is noteworthy that many of the metro areas in the Southeast—a region with relatively low electricity prices and lower average incomes—faced the highest energy burdens compared with cities nationally. As we describe further in the text box “The Relationship between Energy Burden and Energy Prices,” low electricity prices do not equate to low bills. Figure 2 provides a visual

FIGURE 2. Median metro-area energy burden for all households

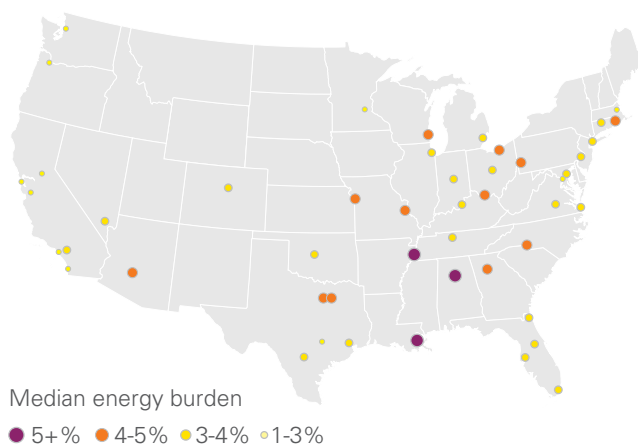


TABLE 3. Median income, utility bill, energy burden, and unit size for households based on income type, building type, building ownership, and household race for groups across all metro areas

	Household type	Median annual income	Median size of unit (square feet)	Median annual utility spending	Median annual utility costs per square foot	Median energy burden ¹
Income type	Low-income ² (≤80% AMI ³)	\$24,998	1,200	\$1,692	\$1.41	7.2%
	Non-low-income	\$90,000	1,800	\$2,112	\$1.17	2.3%
Building ownership	Low-income multifamily (≤80% AMI)	\$21,996	800	\$1,032	\$1.29	5.0%
	Non-low-income multifamily	\$71,982	950	\$1,104	\$1.16	1.5%
	Renters	\$34,972	1,000	\$1,404	\$1.40	4.0%
	Owners	\$68,000	1,850	\$2,172	\$1.17	3.3%
Head-of-household race	White	\$58,000	1,600	\$1,956	\$1.22	3.3%
	African-American	\$34,494	1,290	\$1,920	\$1.49	5.4%
	Latino	\$39,994	1,200	\$1,704	\$1.42	4.1%
All households	N/A	\$53,988	1,573	\$1,932	\$1.23	3.5%

¹ Energy burden is the percentage of household income that is spent on energy bills. To calculate median energy burden, we calculated energy burden for each household, then took the median. This value differs from the median energy burden that is calculated using median annual utility spending and income.

² Low-income includes both single- and multifamily households.

³ Area median income (AMI) is the median dollar amount that divides the population into two equal parts.

Source: American Housing Survey (Census Bureau 2011 and 2013a).

representation of the median energy burdens in metro regions across the country. See Appendix B for the median energy burden values for each city.

The five cities with the lowest median energy burdens were San Francisco (1.4%), San Jose (1.8%), Seattle (2.1%), Washington, DC (2.1%), and San Diego (2.3%). In these cities, households spent less of their overall income on utility bills, which could be due to a combination of lower energy bills and higher household income throughout the metro areas, and/or more efficient buildings and energy use.

Currently, we cannot make causal arguments about why a city has either a high or low energy burden. Factors such as the efficiency of housing stock and the effectiveness and reach of energy efficiency investments, among other factors, may play a role. More research is needed to understand the drivers of energy burdens in specific geographical areas.

Results: Energy Burden Trends by Household Group

We compared various household groups in our sample to identify overall energy burden trends. Table 3 includes median income, housing unit size, annual utility bills, annual utility spending per square foot, and energy burden for these groups across all metro areas.

Median energy burdens in low-income households were more than three times higher than in non-low-income households (7.2% and 2.3%, respectively). Higher energy burdens result in part from lower income. The data also show these households have

higher energy cost per square foot than the average household, which could indicate lower efficiency of the housing unit itself. We discuss this point in greater detail below. The situation for multifamily households was similar. The median low-income multifamily household experienced an energy burden more than three times higher than that of the median non-low-income multifamily household (5.0% and 1.5%, respectively) and had higher utility cost per square foot.²¹ Renters were also disproportionately impacted. The median renter experienced an energy burden greater than that of the median owner (4.0% and 3.3%, respectively).

We also found that energy burdens were related to the race of householders. On average, African-American and white households paid similar utility bills, but African-American households experienced a median energy burden 64% greater than white households (5.4% and 3.3%, respectively). Latino households paid lower utility bills, on average, than African-American and white households did, yet they experienced a median energy burden 24% greater than white households (4.1% and 3.3%, respectively).

Looking at how inefficient housing contributes to this issue, we calculated what the energy burdens for various categories would be if their housing stock were as efficient as the median—i.e., if their energy expenditures per square foot were the same as the median for all households. Then, for each category, we calculated the proportion of the excess energy burden (the difference between category median burdens and the all-household median burden) that would be eliminated if their housing stock were brought up to the efficiency standard of the all-household median.

THE RELATIONSHIP BETWEEN ENERGY BURDEN AND ENERGY PRICES

Many people confuse their high energy bills with high electricity and gas prices. However our findings show that low prices do not necessarily mean low bills. Consider that, in 2014, three of the five states with the highest average monthly utility bills for households—Alabama, South Carolina, and Mississippi—were states with average (not high) electricity prices and a wide range of gas prices. Our study found that the Southeast and Midwest regions, while having among the lowest average prices, also had the highest average metropolitan energy burdens. In 2014, New Orleans and Memphis were among the five cities in our sample with the lowest average electricity prices (both \$0.10/kWh) and average gas prices (\$10.9 and \$10.1/1,000 ft³). Even with these low prices, these two cities are in the top three for highest average energy burden for all households, at 5.27% and 6.18%, respectively. Therefore, it is important to recognize that factors beyond prices—such as lower incomes and inefficient housing stock—contribute to high energy bills.

We found that for all low-income households and for multifamily low-income households, bringing their housing stock up to the efficiency level of the median household would eliminate 35% of their excess energy burden. As one might expect, the energy burdens of low-income households are driven in large part by their low-income status. However more than one-third of their excess energy burden was caused by inefficient housing stock. Bringing their homes up to median efficiency would lower their energy burden from 7.2% to 5.9%. For African-American and Latino households, 42% and 68% of the excess energy burden, respectively, was due to inefficient homes. For renters that number was 97%, meaning that almost all of their excess energy burden could be eliminated by making their homes as efficient as the median.

Far from being an intractable problem related to persistent income disparity, the excess energy burdens they face are directly related to the inefficiency of their homes. This is important not only for understanding how best to address the problem for various populations, but also to correct any misconceptions that the energy burden problem is a

We found that for all low-income households and for multifamily low-income households, bringing their housing stock up to the efficiency level of the median household would eliminate 35% of their excess energy burden.

driven purely by income, a perception that might be reinforced by the stark differences in incomes shown in table 3.

Results: Energy Burdens by City and Household Groups

When we examined specific demographic groups across different cities, we found that many of these groups experienced energy burdens greatly exceeding

TABLE 4. Energy burdens for demographic groups in the 10 cities with the highest energy burdens

	All households	Low-income households*	Low-income multifamily households	African-American households	Latino households	Renting households
1	Memphis (6.2%)	Memphis (13.2%)	Memphis (10.9%)	Memphis (9.7%)	Memphis (8.3%)	Memphis (8.6%)
2	Birmingham (5.3%)	Birmingham (10.9%)	Birmingham (8.7%)	Pittsburgh (8.3%)	Providence (7.3%)	Birmingham (7.3%)
3	New Orleans (5.3%)	Atlanta (10.2%)	Atlanta (8.3%)	New Orleans (8.1%)	Philadelphia (7.3%)	Atlanta (6.8%)
4	Atlanta (5.0%)	New Orleans (9.8%)	Providence (7.1%)	Kansas City (7.9%)	Kansas City (6.6%)	New Orleans (6.3%)
5	Providence (4.7%)	Providence (9.5%)	Pittsburgh (7.1%)	Birmingham (7.7%)	Atlanta (6.6%)	Providence (6.2%)
6	Pittsburgh (4.5%)	Pittsburgh (9.4%)	New Orleans (6.9%)	Milwaukee (7.4%)	Birmingham (6.6%)	Kansas City (6.1%)
7	Kansas City (4.5%)	Dallas (8.8%)	Columbus (6.5%)	St. Louis (7.4%)	Phoenix (6.0%)	Pittsburgh (6.0%)
8	Fort Worth (4.4%)	Philadelphia (8.8%)	Dallas (6.5%)	Cleveland (7.0%)	Dallas (6.0%)	Cincinnati (6.0%)
9	Cincinnati (4.3%)	Kansas City (8.5%)	Indianapolis (6.5%)	Cincinnati (6.9%)	Fort Worth (5.7%)	St. Louis (5.9%)
10	Dallas (4.3%)	Cleveland (8.5%)	Kansas City (6.3%)	Atlanta (6.6%)	Detroit (5.7%)	Cleveland (5.5%)

* Low-income includes both single- and multifamily households.

the city median, ranging as high as 13% for some groups (see Appendix B). Table 4 gives details for the 10 cities with the highest overall median energy burdens, as per figure 1. For example, low-income households face the greatest energy burden in Memphis (13.2%), Birmingham (10.9%), and Atlanta (10.2%), and African-American households face the greatest energy burden in Memphis (9.7%), Pittsburgh (8.3%), and New Orleans (8.1%).

For example, the median low-income energy burden in Atlanta was 10.2%, meaning that half of the city's low-income households experienced an energy burden greater than 10.2%. Looking at the highest energy burden quartile in Atlanta, we can see that 25% of the low-income population experienced an energy burden greater than or equal to 18.2%. This is more than three times the city median of 5.0%. Results for the 10 cities with the highest energy burdens are detailed in table 5.

Results by Energy Burden Quartile

We also calculated energy burden for the highest energy burden quartile households in each group (see Appendix C). Simply looking at the median does not provide insight into the distribution across the group and does not properly represent the range of experiences of those who are the worst off within these groups. We can better understand this by comparing the energy burden of the household at the median and the highest quartile of energy burdens.

In Atlanta, we can see that 25% of the low-income population experienced an energy burden greater than or equal to 18.2%. This is more than three times the city median of 5.0%.

TABLE 5. Highest energy burden quartiles in the 10 cities with the highest energy burdens

	All households	Low-income households*	Low-income multifamily households	African-American households	Latino households	Renting households
1	Memphis (12.8%)	Memphis (25.5%)	Memphis (21.8%)	Memphis (19.4%)	Memphis (15.9%)	Memphis (18.5%)
2	Birmingham (10.8%)	New Orleans (18.9%)	Birmingham (16.2%)	New Orleans (16.4%)	Philadelphia (15.7%)	Birmingham (15.1%)
3	New Orleans (10.0%)	Birmingham (18.8%)	Atlanta (15.7%)	Kansas City (16.2%)	Pittsburgh (12.4%)	Atlanta (13.3%)
4	Atlanta (9.7%)	Atlanta (18.2%)	Pittsburgh (15.7%)	Pittsburgh (16.1%)	Kansas City (12.0%)	St. Louis (12.9%)
5	Providence (8.7%)	Philadelphia (16.7%)	Chicago (14.6%)	Cincinnati (15.6%)	Providence (11.7%)	New Orleans (12.6%)
6	Pittsburgh (8.6%)	Providence (16.7%)	Cincinnati (13.0%)	Milwaukee (15.5%)	Atlanta (11.5%)	Cincinnati (12.1%)
7	Cincinnati (8.5%)	Pittsburgh (15.7%)	St. Louis (12.9%)	Birmingham (15.4%)	Hartford (11.1%)	Cleveland (11.9%)
8	Kansas City (8.4%)	Cincinnati (15.5%)	Cleveland (12.3%)	Chicago (15.3%)	Phoenix (10.7%)	Pittsburgh (11.9%)
9	Philadelphia (8.3%)	Detroit (15.3%)	Hartford (11.8%)	Detroit (14.8%)	Birmingham (10.4%)	Providence (11.7%)
10	Dallas (8.2%)	St. Louis (14.8%)	Fort Worth (11.4%)	St. Louis (14.4%)	Detroit (10.2%)	Kansas City (11.7%)

* Low-income includes both single- and multifamily households.

FIGURE 4. Low-income ($\leq 80\%$ AMI) household energy burdens for the median, highest energy burden quartile, and lowest energy burden quartile households for each metro area. The orange bars represent the beginning of the quartile of low-income households with the lowest energy burden. The blue bars represent the beginning of the quartile of low-income households with the highest energy burden. These data include both single- and multifamily low-income households.

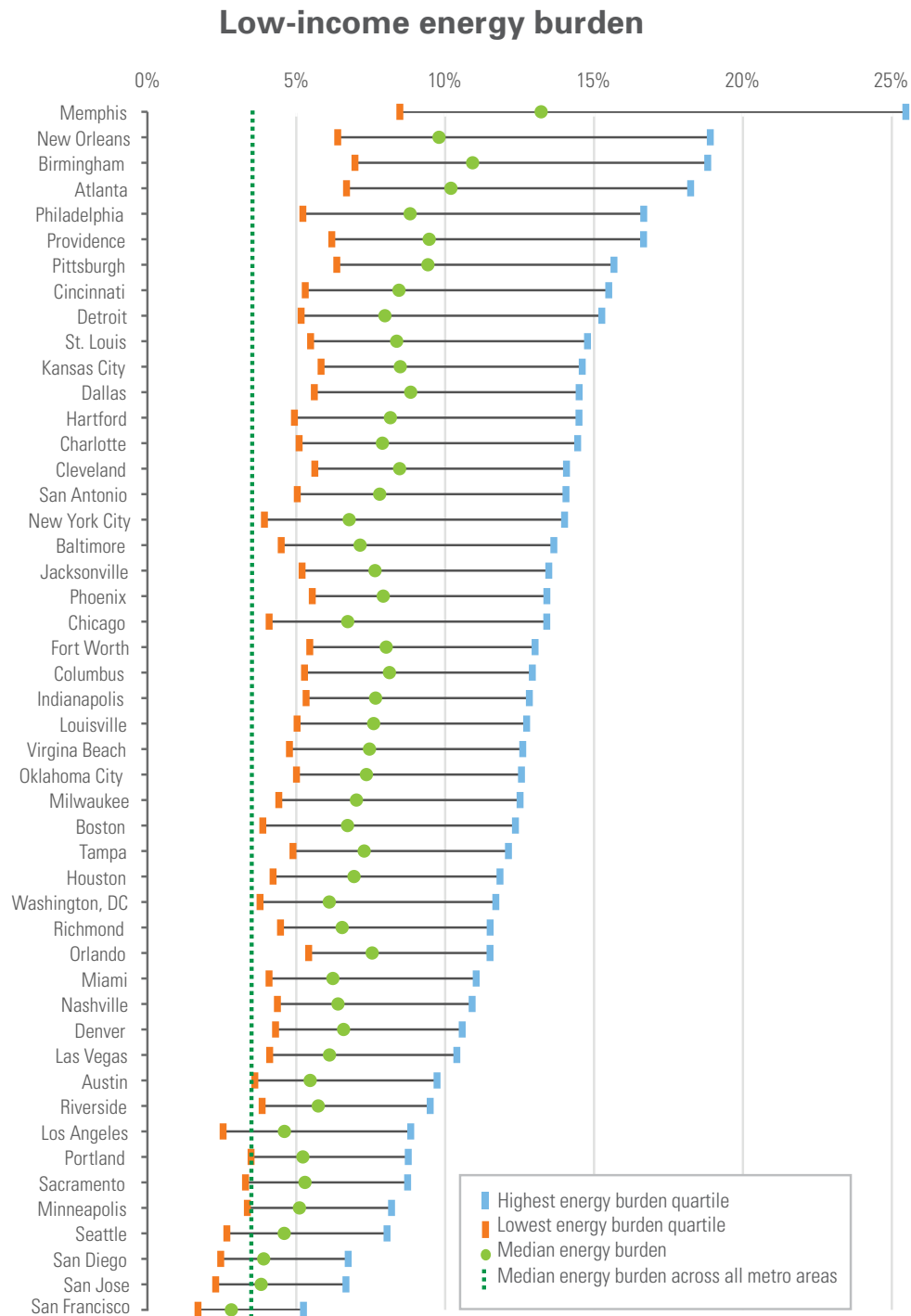


Figure 4 provides a more detailed representation of the energy burden faced by low-income households in each metro area. Across the metro areas in our sample, based on our definition of “low-income” ($\leq 80\%$ of AML), low-income households made up 44% of all households included in our analysis (see Appendix A). Figure 4 highlights the household energy burdens for the highest and lowest quartiles, as well as the median energy burden for all low-income households. For comparison, the figure also includes a line indicating the median energy burden for all households across all metro areas in the sample.

For low-income households, the range of energy burdens varies greatly across and within cities. For example, one-fourth of low-income households in Nashville had an energy burden below 4.4%, one-fourth had an energy burden between 4.4% and the median of 6.4%, one-fourth had an energy burden between 6.4% and 10.9%, and one-fourth had a burden greater than 10.9%. The data, presented in this way, are useful for understanding the depth of the low-income energy burden in cities. In 17 cities, a quarter of low-income households experienced an energy burden greater than 14%.

In 17 cities, a quarter of low-income households experienced an energy burden greater than 14%.



Additionally, we assessed the energy burden for certain households and examined the proportion of residents that experienced an energy burden greater than or equal to twice the city median. We include this analysis in Appendix D. For all the cities in the sample, at least 38% of low-income households experienced an energy burden that was twice the city median.

Results: Regional Energy Burden Trends

In this section, we examine regional energy burden data for our select groups in more detail. Figure 5

shows the regional median energy burden for each group and for all households. In Appendix E, we include similar graphs for each region.

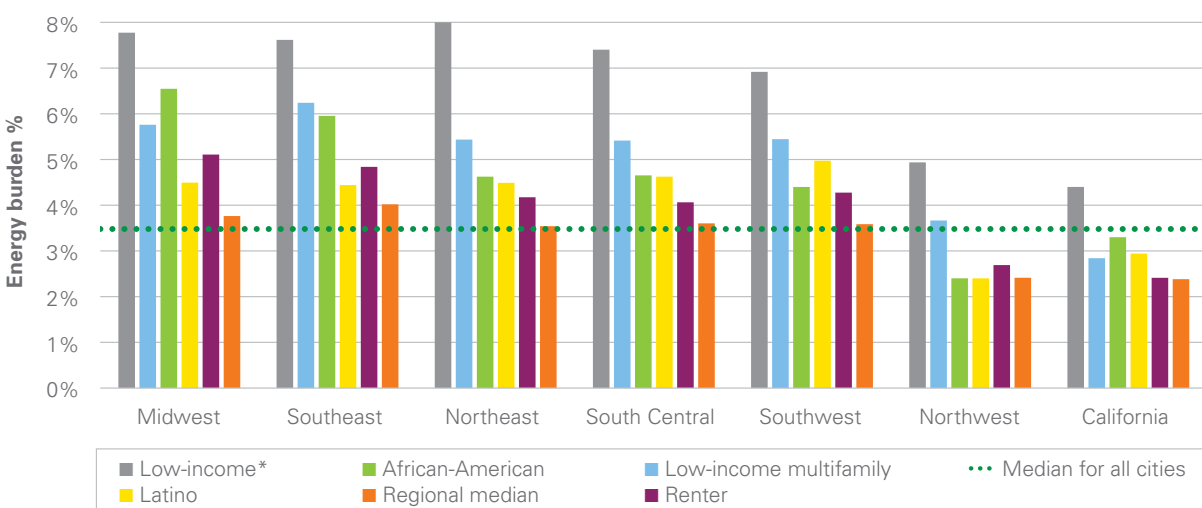
Metro areas in the Midwest and Southeast had the highest median energy burdens across all groups, with African-American and low-income multifamily households the worst-off in these regions.

Low-income households—including both single- and multifamily—had the highest energy burden in each region and were the worst-off across Northeastern metro areas. While we cannot attribute with certainty

REGIONAL TRENDS IN UTILITY ENERGY EFFICIENCY INVESTMENTS

We found that many cities with little to no investment in utility energy efficiency programs also experienced higher average energy burdens. Programs that help households save energy are often administered by the local utility. Utilities taking the lead on energy efficiency provide an array of programs for commercial and residential customers. Some localities and states will adopt energy savings targets or requirements to encourage and guide utility program spending and design. According to the rankings in *The 2015 City Energy Efficiency Scorecard* issued by ACEEE, the utilities with the least spending on energy efficiency programs were those serving southeastern cities. All of the southeastern cities in the *Scorecard* fell within the bottom 40% of the ranking (Ribeiro et al. 2015b). The cities with the most energy efficiency investment in 2015 were Boston, Minneapolis, Portland (Oregon), Chicago, and San Francisco. However, even when cities do have strong utility programs, there is no guarantee that low-income households will benefit. Information on what types of households are currently being served by energy efficiency programs is crucial to ensuring that these programs reach a diverse set of households.

FIGURE 5. Energy burden of select groups by region, ordered from highest to lowest based on the average of the median energy burdens across all groups.



the drivers of high energy burden within specific regions and cities, we know that numerous factors are at play. Southeastern households have the lowest median incomes in the country, which likely contributes to higher energy burdens. In terms of energy prices, the Southeast, Midwest, and Northwest regions have the lowest average electricity prices, but at the same time, they also have the highest average energy burdens. This indicates that low electricity and gas prices do not necessarily lead to low bills or affordable

energy (see earlier text box “The Relationship between Energy Burden and Energy Prices”). Although we do not know the relative efficiency of housing stock in the Southeast, we do know that the southeastern utilities serving major cities currently have the lowest investment in energy efficiency programs as compared with other regions (see text box “Regional Trends in Utility Energy Efficiency Investments”). Low energy prices therefore do not compensate for the lack of energy efficiency investment or low incomes.

Metro areas in the Midwest and Southeast had the highest median energy burdens across all groups, with African-American and low-income multifamily households the worst-off in these regions.

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- 14 Area median income (AMI) is the median dollar amount that divides the population into two equal parts. HUD uses AMI to determine eligibility for low-income programs based on metropolitan area and household size.
- 15 Sample sizes in some cities for Latino households (Birmingham, Cincinnati, Detroit, Louisville, Pittsburgh, and St. Louis) and African-American households (Portland) were small. See Appendix A for sample sizes for each group by city.
- 16 A metropolitan statistical area (MSA) is a geographical region typically made up of several counties, with a core urban area having a population of 50,000 or more. MSAs, therefore, include a central city and surrounding suburbs. Raleigh and Salt Lake City, two of the top 50 MSAs, were not included in the AHS 2011 and 2013 and therefore were not included in this analysis. See Appendix A for the corresponding year of data for each MSA—either 2011 or 2013.
- 17 See Appendix A for sample sizes for each group studied after filtering for these variables.
- 18 Total utility spending includes average annual spending on electricity and heating fuels, as reported. Total gross household income includes all annual income reported by all household members, including all government assistance.
- 19 By using medians for both income and energy costs, we were able to arrive at a truer median, as the data distributions for income and energy costs differed greatly.
- 20 We should note that we are comparing a median energy burden in metro areas with an average energy burden statewide. By using an average, the data may be skewed toward higher values because there is a zero lower bound on energy burden and no upper bound.
- 21 Single-family low-income households experienced the highest average energy burden of 7.8%. We did not specifically analyze these households in this study.

Policies and Programs to Address High Energy Burdens



In the following sections of this report, we discuss policies and programs that address high energy burdens, with a focus on energy efficiency. Reducing the impact of high energy burden has been a long-standing policy goal at the local, state, and national levels. Policy has focused on three main intervention programs: bill payment assistance, weatherization, and utility-funded efficiency programs (see table 6).

These efforts aim to address the two factors that impact energy burden: low income and high energy bills. Federal, state, local, and utility funding supports these programs as well as other, related programs that focus on health and safety, behavior, and education.²²

Policymakers and program administrators design these programs to address high utility bills, inefficiencies in housing units, and lack of awareness in regard to energy efficiency programs and actions that customers can take.

TABLE 6. Policies and programs for addressing high energy burden

Program type	Program	Funding source
Bill assistance	Low Income Home Energy Assistance Program (LIHEAP)	Federal and state taxpayers
	Other low-income bill assistance programs	Utility ratepayers; private contributions
	Modified rate design, rate discounts or waivers, and modified billing methods	Utility ratepayers
Weatherization	Weatherization Assistance Program (WAP)	Federal and state taxpayers
Energy efficiency	Low-income energy efficiency programs ¹	Utility ratepayers ²

¹ Customer benefit surcharges are collected through customer utility bills. Public utility commissions or city councils set these charges, and the utility uses this money to fund energy efficiency and energy education programs. ² Non-utility entities can also fund low-income energy efficiency programs, such as the Regional Greenhouse Gas Initiative (RGGI), Qualified Energy Conservation Bonds (QECBs), state treasury funding, and general obligation bonds (EPC 2013b; RGGI 2015; Brown 2008).

Funding for low-income programs varies by program type. Figure 6 illustrates the allocation of funding from ratepayer-funded bill assistance and energy efficiency programs, the Weatherization Assistance Program (WAP), and the Low Income Home Energy Assistance Program (LIHEAP). As indicated in the chart, the overwhelming majority of program support—about 81%, or \$6.31 billion—goes toward helping customers pay their utility bills. Energy efficiency programs receive about 14% of program support (\$1.17 billion), and the remaining 5% of program support (\$38 million) is unspecified (LIHEAP Clearinghouse 2016). While bill assistance programs provide important, immediate relief to distressed households, energy efficiency investment appears to be an underutilized strategy for addressing energy affordability. Increased investment, expanded reach, and improved design of energy efficiency programs could better complement bill assistance and weatherization programs.

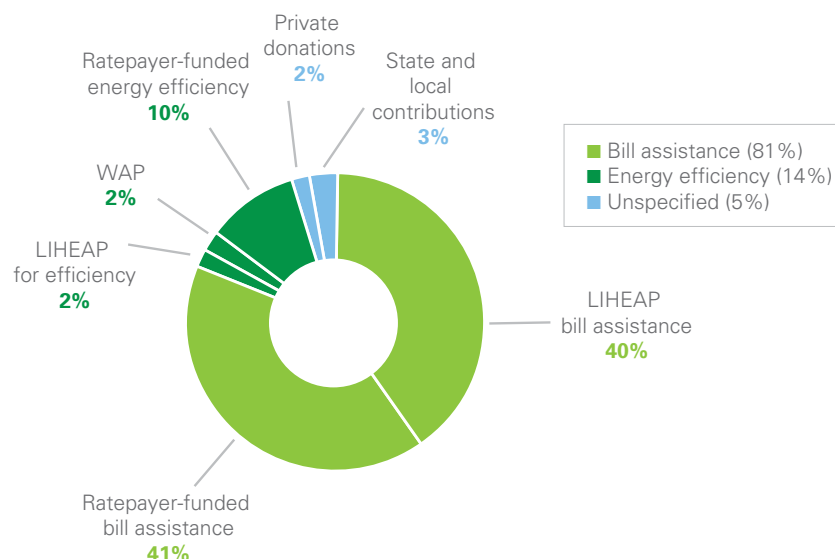
Increased investment, expanded reach, and improved design of energy efficiency programs could better complement bill assistance and weatherization programs.

Assistance Program (LIHEAP) is the primary vehicle for bill assistance. LIHEAP provides funding to states, based on a formula, and then states allocate this funding to qualified households according to established federal parameters. Funds can take the form of direct bill assistance, crisis assistance, support for weatherization programs, or other aid to reduce household energy needs (Perl 2012). The bulk of funding, however, goes toward energy bill assistance and ends up with utilities. States typically determine household eligibility for bill assistance as between 150% and 110% of the federal poverty line, or 60% of the state median income.

Bill Assistance Programs

Bill assistance programs provide financial assistance to help families pay their immediate home energy bills. The federally funded Low Income Home Energy

FIGURE 6. Support for low-income energy needs. Data on ratepayer-funded bill assistance, ratepayer-funded energy efficiency, WAP, and LIHEAP assistance are from 2013. LIHEAP spending on efficiency is approximated based on 6% of LIHEAP funds spent on efficiency in 2006. Data on state and local contributions and private donations are from 2010. Data collected from the LIHEAP Clearinghouse in 2016. Source: Cluett, Amann, and Ou 2016.



LIHEAP serves between 20 and 25% of eligible households, about 7.6 million in 2009 and 8.3 million in 2010 (Jackson 2011). Other bill assistance programs help to meet the overwhelming need, such as voluntary utility customer contributions to cold weather funds and other forms of bill assistance, programs supported by charitable groups, and, in some cases, structured payment programs offered by utilities. Agencies that provide weatherization services may also deliver LIHEAP assistance. In these cases, LIHEAP eligibility can act as a gateway for weatherization and low-income energy efficiency programs. Bill assistance programs remain critical for alleviating the *immediate* energy burden that many households face, but they could be better coordinated with weatherization and other energy efficiency programs to provide upgrades that can reduce energy burden over the long term.

Weatherization Programs

Weatherization programs address the longer-term energy needs of households by making home repairs that reduce high energy bills. By upgrading the efficiency of homes, programs can then reach more customers who need immediate assistance with more persistent intervention. Weatherization programs consist of energy efficiency measures aimed at improving the building envelope, such as weather-stripping doors and windows, air sealing, and installing insulation. In some cases, weatherization includes upgrades or repairs to heating and cooling systems and the reduction of electric baseload consumption through energy efficiency measures such as lighting and appliances, but these measures are less common among typical weatherization programs.

The federal government, state governments, and utilities all fund and sponsor weatherization programs. The US Department of Energy's Weatherization Assistance Program (WAP) historically has been the largest funder of these programs. Because states can choose to allocate funding from LIHEAP toward weatherization programs, LIHEAP funding (as well as state and local funding) supplements WAP in many states. Households with income up to 200% of the

federal poverty line qualify for WAP funding. WAP estimates that 38 million households qualify for the program and that of these, approximately 15 million are good candidates for cost-effective weatherization (WAPTAC 2016). Over the history of the program, WAP has served about 7 million households (Benefits.gov 2015). Numerous factors limit the reach of the federal program, such as funding, capacity of implementing agencies, and the necessity of making health and safety improvements before weatherization can begin.²³

The most effective weatherization programs address the largest household energy uses with the longest sustained savings (e.g., heating and cooling systems), which often have the greatest impact on reducing energy burdens. Low-income housing units can also require substantial structural improvements before energy efficiency measures can be implemented; these can be costly and require large up-front investment. However many researchers have proved these programs to be cost effective in the long run. The Department of Energy determined that, on average, the value of efficiency upgrades is 2.2 times greater than their cost (DOE 2015). This value does not come from energy savings alone, as WAP also aims to improve health, safety, and security for participating households. When program evaluators include all of these multiple benefits into cost-benefit analyses, WAP proves to be a cost-effective solution to improving energy affordability.

Utility Energy Efficiency Programs

Many utilities provide energy efficiency programs that target low-income households. These programs are funded through customers (or "ratepayers"). Such programs generally have a very good record of delivering cost-effective energy savings as a resource to the entire utility system. Unlike bill assistance and most weatherization programs, utility energy efficiency programs can include a variety of program strategies.²⁴ Some utility energy efficiency programs operate in tandem with local or statewide weatherization efforts, using similar channels to reach customers.

When program evaluators include all of these multiple benefits into cost-benefit analyses, WAP proves to be a cost-effective solution to improving energy affordability.

Typical low-income programs focus on single-family whole-house retrofits (Cluett, Amann, and Ou 2016; Hoffman et al. 2015). These programs can mirror other residential energy efficiency programs offered by utilities or weatherization implementers; they often focus on specific measures and provide higher incentives. The most common low-income energy efficiency approaches are of two types: comprehensive weatherization, and the direct installation of low-cost energy efficiency measures (e.g., efficient lighting, high-efficiency showerheads and faucet aerators, and air infiltration reductions). Some utilities operate direct-install programs targeting multifamily rental buildings as part of their low-income program offerings. Other, less common low-income programs include conservation kits, product rebates, appliance recycling, and programs that promote behavioral change or provide information on home energy use (Cluett, Amann, and Ou 2016).

Low-income households in multifamily buildings can also be reached through whole-building programs that target these buildings and typically require the participation of only the building owner. In most cases, energy efficiency retrofits and measures provide energy bill reduction for both owner and residents. There are three types of program models that utilities typically use to serve their multifamily customers: direct install services, equipment and product rebates, and comprehensive energy retrofits for existing buildings and new construction (Johnson and Mackres 2013). In some cases, these programs

Despite the existence of such programs, low-income households remain a hard-to-reach group with many barriers to participation.

are adapted to meet the needs of properties that house low-income residents by offering higher incentives or additional measures.

Despite the existence of such programs, low-income households remain a hard-to-reach group with many barriers to participation. Most utilities have found that their energy efficiency program strategies do not adequately reach these households (Rasmussen et al. 2014). Low-income households and owners of multifamily buildings that provide affordable housing may find it challenging to participate in residential low-income energy efficiency programs that require a copay. These households may also lack the time, resources, and up-front capital to register and participate. As a result, many low-income programs offer free or discounted direct-install measures, such as efficient lighting, low-flow showerheads, smart thermostats, and/or smart power strips in order to facilitate program participation.

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- 22 At times, low-income programs that address health and safety issues are implemented in conjunction with weatherization programs to provide the most comprehensive offering. These programs make sure the house is fit from a health and safety perspective before it undergoes weatherization (Wilson and Katz 2010). Behavior and education programs can also supplement low-income assistance and energy efficiency programs. These programs typically provide educational material on energy saving behaviors, feedback on customer energy use, or games and other interactive measures to encourage energy savings (Mazur-Stommen and Farley 2013).
- 23 Spending on WAP is historically low. However, as a part of the American Recovery and Reinvestment Act of 2009, WAP received \$5 billion over the course of 2009, 2010, and 2011, which is about 25 times the funding the program has received in each year since (LIHEAP Clearinghouse 2016).
- 24 For more information on best practices for low-income utility programs, see Cluett, Amann, and Ou 2016.

Benefits of Investing in Energy Efficiency in Low-Income Communities



Low-income energy efficiency programs provide benefits that go beyond reduced utility bills and beyond benefits experienced by direct participants. In table 7, we categorize these benefits as those received by participating low-income households, by utilities and ratepayers, and by the wider community. These values can justify policy decisions to increase such investments.

Low-income households participating in energy efficiency programs report direct benefits that improve their quality of life. For example, energy efficiency investments lower energy bills, which reduces energy burden, eases economic and social stresses, and provides families with more disposable income that can be spent on other necessities beyond energy (e.g., medicine, food, transportation) (Tonn et al. 2014). Building efficiency upgrades also increase property value and the reliability of appliances and HVAC equipment, which reduces maintenance costs and stress (Cluett and Amann 2015). Multiple case studies by the New York State Energy Research and Development Authority (NYSERDA) found that energy efficiency programs also increase tenant comfort

and provide tenants with more control over their surroundings (NYSERDA 2013a; NYSEDA 2013b). These benefits occur as a result of both single- and multifamily energy efficiency projects, though some benefits—such as increased property value—accrue only to the building owner in cases where the household rents the unit (Russell et al. 2015).

In affordable multifamily housing, the cost of energy is typically the highest controllable operating expense. Reducing operating expenses allows affordable housing providers to maintain reasonable rents, invest in resident services, and make necessary building improvements. Energy efficiency can also help low-income households manage bills in the event of utility

TABLE 7. Energy efficiency benefits for low-income households, utilities, and communities

Benefit recipient	Energy efficiency outcome	Resulting benefit
Low-income program participants	Lower monthly utility bills	Lower household energy burden and greater disposable income
		Reduced stress and fewer trade-offs between energy and other necessities
		Reduced exposure to risk from utility rate increases
	Improvements in the efficiency of the housing stock	Improved health and safety and greater household comfort
		Increased property value, more reliable equipment, and lower maintenance costs
		Greater satisfaction with the building/unit and improved household and neighborhood stability
Utilities and ratepayers	Demand-side management (both gas and electric)	Avoided excess costs of increased generation, capacity, and transmission investments
		Contribution toward compliance with energy efficiency portfolio standards and other environmental legislation
	Cost savings to utilities and ratepayers	Reduced arrearages and cost of shutoffs, which lowers utility operating costs
		Improved customer service
Communities	Lower electric and gas demand	Reduced environmental pollutants and improved public health
	Lower monthly utility bills due to avoided utility costs	More money spent in the local economy due to greater household disposable income, with higher local multiplier effect
		Poverty alleviation and increased standard of living
	Improvements in the efficiency of the housing stock	Local job creation through weatherization programs and energy efficiency providers and trade allies
		Improved quality of life
		Increased property values and preservation of housing stock

price increases and variable seasons. In 2014, residential electricity prices rose to the highest level in six years, with average electric price increasing by 3.1% annually between 2008 and 2014 (EIA 2015). By improving household efficiency, individuals and communities can be more resilient in times of price increases.

Utilities operate energy efficiency programs because of the benefits that accrue not only to customers but also to the utility system. Investing in low-income energy efficiency can mean avoiding the excess costs of increased energy generation, capacity, and transmission due to reduced demand. The reduction in energy production due to efficiency also reduces environmental pollutants, which helps utilities comply with environmental legislation that limits emissions (Baatz 2015; Brockway, Kallay, and Malone 2014). Energy

By improving household efficiency, individuals and communities can be more resilient in times of price increases.

efficiency investments in low-income communities also reduce the risk of arrearages and the costs of shutoffs for families who have difficulty paying their bills. By lowering these costs, utilities can reduce overall tariffs and charges for their entire ratepayer base.

Although not all low-income customers have the opportunity to participate in their utility's energy efficiency programs, research shows that energy efficiency benefits

the whole community and can be used as a core strategy for increasing energy affordability and community resilience (Ribeiro et al. 2015a). Energy efficiency programs benefit the entire population by reducing environmental pollutants, which tend to impact low-income communities disproportionately (NAACP 2015; EPA 2012). Investments in energy efficiency also stimulate the local economy by providing individuals and families with greater disposable income, alleviating poverty, increasing purchasing power, and creating more local jobs (Bell 2014; IEA 2014).

Last, investing in energy efficiency allows communities to increase their percentage of renewable energy sources. Numerous state and local governments have invested in solar energy projects for low-income

multifamily households; these include the Colorado Energy Office, the District of Columbia Department of Energy and Environment, and the Baltimore Office of Sustainability (Collins 2015; Shahan 2015). By using energy efficiency to lower a building's energy demand, utilities and local governments can maximize the percentage of a building's energy needs that can be met by renewables. Also, because energy efficiency is relatively inexpensive, it can help reduce the total cost per kWh of a combined renewable energy and energy efficiency project. As more states and local governments seek to advance renewable projects in low-income communities—and especially in multifamily housing—energy efficiency can and should play a crucial role in these efforts.

Energy efficiency programs benefit the entire population by reducing environmental pollutants, which tend to impact low-income communities disproportionately.

Strategies for Improving Energy Efficiency in Low-Income Communities



When developing energy efficiency policies and programs, policymakers and other stakeholders must consider the extent to which these investments will reach the target populations, especially those experiencing persistent and high energy burdens. Individuals or families experiencing high energy burdens vary in important ways relevant to program design: by ownership, income, building type, race/ethnicity, energy use per square foot, and languages spoken (Berelson 2014). Therefore, programs and policies should be designed, targeted, and implemented with the goal of reaching a wide variety of households facing high energy burdens.

Based on research, experience, and findings in other reports, we suggest the following strategies for improving energy efficiency in low-income communities:

- Improve and expand low-income utility programs
- Collect, track, and report demographic data on program participation
- Strengthen policy levers and more effectively leverage existing programs
- Utilize the Clean Power Plan to prioritize investment in low-income energy efficiency

Utilities and state and local governments can utilize these strategies to create more effective low-income energy efficiency programs. These strategies should

be used in combination, and they should be prioritized according to the needs of the community.

Improve and Expand Low-Income Utility Programs

Take advantage of best practices in low-income energy efficiency program design and delivery

Utilities and other program administrators can increase the impact of their low-income programs by taking advantage of best practices in low-income energy efficiency program design and delivery. In doing so, they must recognize the diversity of the low-income housing stock, including renter- and owner-occupied housing as well as single- and multifamily units.

In regard to single-family housing, successful low-income energy efficiency programs have been found to

- offer a range of measures and services
- coordinate delivery with other organizations
- align and add on to existing weatherization efforts
- address health and safety issues when implementing efficiency measures
- incorporate strategies for customer energy efficiency education

Some programs may also coordinate efficiency with bill assistance programs and develop dual-fuel and fuel-blind programs to make program delivery seamless. Examples of utilities and other program administrators that run strong low-income energy efficiency programs include Southern California Edison, Efficiency Vermont, National Grid, and Pacific Power. For a more comprehensive discussion of successful low-income utility programs, see ACEEE's 2016 report *Building Better Energy Efficiency Programs for Low-Income Households* (Cluett, Amann, and Ou 2016).

To achieve greater savings within this sector, utilities can offer more comprehensive programs that meet the needs of a diverse low-income customer base. These programs could include direct-install and weatherization measures, as well as appliance, equipment, and electronics upgrades. Currently, the majority of low-income energy efficiency programs offered by utilities focus on the weatherization model and direct-install measures, with the most common ones including insulation, air sealing, and heating and cooling measures (Cluett, Amann, Ou 2016). Some utility programs go beyond weatherization and incorporate additional offerings, such as energy efficiency equipment upgrades and initiatives that encourage behavioral change.

Utilities are well positioned to serve low-income customers with energy efficiency programs. They already have built-in communication channels and relationships with households and building owners who receive their energy bills. Some utilities have also built strong partnerships with trusted community organizations to disseminate information and run programs. For example, utilities can expand low-income energy efficiency programs alongside WAP implementation in order to best leverage delivery channels and program strengths and resources (Cluett, Amann, and Ou 2016). In order to better inform the design and delivery of low-income energy efficiency

programs, state and local governments can partner with utilities and local organizations that already work on outreach to low-income communities. Local governments can also assist with joint delivery of energy efficiency programs with other low-income services in order to streamline program delivery and maximize participation.

Develop Programs Targeted to Affordable Multifamily Housing

In many states the majority of low-income households are renters. Yet residential energy efficiency programs administered by states and utilities have historically focused on single-family, owner-occupied housing. Efficiency measures are far less likely to be installed in multifamily rentals than in any other type of housing, leaving significant unrealized energy savings (Pivo 2014). A recent study issued by Energy Efficiency for All estimates that energy efficiency in multifamily affordable housing could realistically cut the sector's electricity usage by as much as 26%, based on data from a sample of states (Mosenthal and Socks 2015).

Utilities and other program administrators should develop programs to target multifamily customers. In 2013, ACEEE completed a review of leading multifamily programs and identified 10 best practices among these programs (Johnson 2013):

- provide a one-stop shop for program services
- incorporate on-bill repayment or low-cost financing
- integrate direct installation and rebate programs
- streamline rebates and incentivize in-unit measures to overcome split incentives
- coordinate programs across electric, natural gas, and water utilities
- provide escalating incentives for achieving greater savings levels
- serve both low-income and market-rate multifamily households
- align utility and housing finance programs
- partner with the local multifamily housing industry
- offer multiple pathways for participation to reach more buildings

Program administrators designed these programs specifically to serve multifamily customers, often targeting building owners who have a budget for repairs and improvements. As a result, these programs often address the specific needs identified for this market.

Work with Utility Regulators and Utilities to Document and Recognize the Nonenergy Benefits of Low-Income Energy Efficiency Programs

Program administrators do not often include nonenergy benefits in their pre- and post-program cost-benefit analyses, even though programs often have purposes beyond energy savings, such as addressing health and safety measures and increasing energy affordability (Cluett, Amann, and Ou 2016). A 2012 ACEEE study found that less than one-third of sampled utilities included the multiple and nonenergy benefits of energy efficiency in their cost-benefit testing, although three-fourths did include all participant costs. Of the utilities that included multiple benefits, few included comprehensive nonenergy benefits, with utilities in Massachusetts and Rhode Island performing best in this regard (Kushler, Nowak, and Witte 2012).

Both public utility commissions and local governments can encourage or require cost-effectiveness screening and testing to take into account the multiple benefits of low-income energy efficiency programs.

When program administrators include the nonenergy benefits of energy efficiency alongside energy savings, the benefit-cost ratio can improve to up to 1.5 times the initial investment for single-family households and up to 3.5 times for multifamily households (Russell et al. 2015; Mosenthal and Socks 2015). Program managers and researchers have not yet come to an agreement on values for nonenergy benefits of energy efficiency, but studies show that these benefits, especially health-related ones, greatly increase the benefit-cost ratio (Skumatz 2014; Oppenheim and MacGregor 2014). Some utilities have found ways

When program administrators include the nonenergy benefits of energy efficiency alongside energy savings, the benefit-cost ratio can improve to up to 1.5 times the initial investment for single-family households and up to 3.5 times for multifamily households.

to account for these benefits, such as by using an adder in the cost-benefit calculation. An adder is a factor that adjusts the calculated benefit of an energy efficiency measure on the basis of its perceived value, including nonenergy benefits. In other words, while certain benefits may be difficult to measure, it is more accurate to use an approximation than to use zero.

By including costs and excluding some benefits, the evaluation of low-income programs might not reflect their full value. If tests measure only energy-related benefits, then costs not associated with energy—such as health- and safety-related home repairs and job training—should not be included. In order to produce more accurate results, benefit-cost tests should include only costs and benefits related to energy savings or include all energy and nonenergy costs and benefits.

Some states—including Connecticut, California, and New Hampshire—acknowledge that low-income programs provide benefits beyond energy savings (Berelson 2014; Woolf et al. 2013). These states do not apply the same cost-effectiveness standards to low-income programs that they apply to the other energy efficiency programs throughout the state. They recognize difficult-to-measure nonenergy benefits, as well as the fact that the portfolio must include programs that reach low-income households even if those particular programs incur higher costs. Program administrators may set a lower cost-effectiveness threshold for low-income programs, or they may use adders to account for the non-monetized benefits (Cluett and Amann 2015). For example, cost-benefit testing of low-income programs in Colorado assumes an increase in benefits of 25%, and Vermont similarly increases benefits by 15% for low-income programs (Malmgren and Skumatz 2014).

Provide Financing Options to Households and Building Owners

Access to up-front capital is one of the many barriers to energy efficiency for low-income households and low-income multifamily property owners. Several utilities and public and community-based entities have developed financing programs to help these customers access credit to make cost-effective energy efficiency improvements. These programs have the potential to serve as a complement to energy efficiency programs for low-income customers. In the Southeast, electric cooperative utilities are increasingly offering financing

programs that enable households to pay for energy efficiency upgrades via their utility bills. The bill reductions due to energy savings help cover the cost of upgrades (Marsh-Robinson 2016; Lundin 2016). While these programs are typically open to all customers, many low-income households participate.

On-bill financing programs, like most loan products, should include program terms with strong consumer protections. They should also strive to achieve bill neutrality, which means that energy savings from efficiency investments cover the monthly loan payments so the post-investment bill does not exceed the pre-investment amount.²⁵ With strong consumer protections in place, energy efficiency loans can prove beneficial for some households by providing a way to finance efficient and cost-saving measures.

Financing can also be critical to furthering energy efficiency investments in multifamily housing. Multifamily building owners, especially low-income housing providers, face increasing operational costs as their buildings age. Maintenance and improvement priorities often compete with energy efficiency upgrades for limited financial capital, and as a result, building owners often lack the up-front capital needed for energy efficiency retrofits. Low-interest financing or on-bill financing can limit or eliminate up-front costs, allowing building owners to undertake more substantial energy efficiency projects and repay loans with a portion of the energy savings.

Additionally, state housing finance agencies can support energy efficiency in both new and existing affordable multifamily buildings. Their financing programs can require energy efficiency standards in all new construction and rehabilitation that they support in this sector. They can also work with utilities that provide ratepayer-funded programs for multifamily building owners. Utility incentives can be applied to refinance or redevelopment loans to buy down some up-front costs and yield deeper, more comprehensive energy efficiency improvements throughout the affordable building stock.²⁶

Collect, Track, and Report Demographic Data on Program Participation

By collecting demographic data on program participation, utilities can assess the extent to which their programs are serving different segments of the

population, especially those customers known to experience high energy burdens. For example, many utilities do not track the percentage of multifamily customers that they serve relative to the eligible customer base, leaving themselves unaware of the extent to which they are adequately serving these customers. Utilities can rely on this information to inform program design and marketing and outreach strategies. Our research indicates that some of the household demographics that should be incorporated into program evaluation for these purposes include: income level, renter versus owner, multifamily versus single family, and race/ethnicity. These data points and/or evaluations should also be made available to the public for stakeholder review (Kallay et al. 2015).

Even though some utilities do collect demographic data on program participation, few utilities use this information during program evaluation. In a sample of California utility programs, the majority did collect demographic data and published these data in their evaluation reports, but only half of these utilities used the data to make program design recommendations, and even fewer used the data in the analysis of program impact (Frank and Nowak 2016 forthcoming). According to this study, utility program managers most commonly collected data on income and education, with data on home ownership, age, language spoken, and race/ethnicity collected less often.

While some utilities use segmentation to identify customers for specific programs using factors such as geography, income, and energy use per square foot to determine who should be targeted for certain programs, the majority of programs do not use demographic information for evaluation purposes. For many, collecting these data would be a first step toward better program design and measurement. To ensure that energy efficiency programs reach all types of households—especially those experiencing high energy burdens—program administrators should examine demographically identifiable participation gaps in past programs, adjust their program design to target these populations, and continue to collect and analyze these data to measure program success.

Strengthen Policy Levers and Leverage Existing Programs

Utility regulators and boards of publicly owned utilities should help utilities develop, promote, and execute strong low-income programs by approving and

setting goals and guidelines for spending, savings, cost recovery, and cost-effectiveness testing. For municipally owned utilities, city boards and councils can require strong goals and targets for low-income energy efficiency savings and also incorporate cost-effectiveness testing into program evaluation. Even though public utility commissions (PUCs) set goals for investor-owned utilities (IOUs), state and local governments can still encourage PUCs to set low-income program goals and evaluation criteria and can advocate for improved program design and implementation.

Additionally, state and local governments can set policy directives that support low-income energy efficiency, disclosure and benchmarking policies for multifamily buildings, workforce development initiatives, state-level requirements for utility-delivered energy efficiency (e.g., energy efficiency resource standards [EERSs]), and other, related efforts.²⁷

States can also set EERSs that include targets for the low-income sector. Currently, 25 states have an EERS in place, and some of these also have low-income energy-saving goals. Utilities in states that do not have an EERS could also create quantifiable performance indicators (QPIs) that include low-income efficiency programs as a measurement of success.²⁸ For example, Efficiency Vermont includes a minimum acceptable threshold for low-income household participation in programs as one of its QPIs, aiming for \$7.5 million in spending on low-income single- and multifamily programs (Efficiency Vermont 2013). Local governments can support the development of low-income goals and performance indicators by advocating to their PUC, petitioning the utility itself for QPIs, or establishing targets for municipally owned utilities.

Some PUCs also set low-income energy savings goals and spending requirements. For example, the Maine Public Utilities Commission allocates 10% of energy efficiency funds to support low-income programs. Some stakeholders advocate for PUCs to adopt more-stringent goals. Massachusetts's Green Communities Act requires that energy efficiency program funds be allocated in proportion to the customer class from which the funds are contributed but also stipulates that at least 10% for electric and 20% for gas energy efficiency programs be spent on comprehensive low-income programs (Commonwealth of Massachusetts 2008). In Pennsylvania, many community-based organizations, city governments, and local utilities petitioned the PUC to raise its low-income goal. In

June 2015, their efforts succeeded: the PUC increased its low-income target from 4.5% to 5.5% of energy efficiency savings by 2021 (Pennsylvania Public Utility Commission 2016).

Use the Clean Power Plan to Prioritize Investment in Low-Income Energy Efficiency

The Clean Power Plan, announced by President Obama on August 3, 2015, sets the first-ever limits on carbon pollution from power plants—the nation's largest source of the pollution driving dangerous climate

State and local governments can set policy directives that support low-income energy efficiency, disclosure and benchmarking policies for multifamily buildings, workforce development initiatives, state-level requirements for utility-delivered energy efficiency.



change. The US Environmental Protection Agency (EPA) projects that by 2030, the Clean Power Plan will cut the electric sector's carbon pollution by 32% nationally, relative to 2005 levels (EPA 2016). Under the Clean Power Plan, states have the opportunity to develop state plans that apply emissions limits to their power plants. They face several choices in developing these plans, and they can, if they wish, prioritize low-income energy efficiency programs in this process.

To do so, states would first choose a plan approach that incentivizes low-income energy efficiency programs. One way to do this would be to adopt a mass-based plan, which limits the total amount of carbon pollution from the state's power plants. Under this system, the state issues a permit—called an allowance—for each ton of carbon pollution that its power plants are allowed to emit. These allowances have an economic value because they represent the right to emit one ton of a capped pollutant.

Next, states would distribute these allowances in a manner that allowed their value to be captured for public policy purposes, including low-income energy efficiency programs. There are three main ways states can do this. First, they can auction allowances and take in revenue, and then use some of this revenue to fund low-income energy efficiency programs. This is the approach used in the northeastern and mid-Atlantic states in the Regional Greenhouse Gas Initiative, which invested \$1 billion of allowance auction revenue in energy efficiency programs between 2008 and 2013

(RGGI 2015). Second, in states where distribution utilities operate separately from power plant owners (known as deregulated states), allowances can be distributed to the distribution utility, which operates under public utility commission oversight. The distribution utility then sells these allowances and uses the revenue for regulator-approved activities, such as funding low-income energy efficiency programs. Third, states can allocate allowances directly to low-income energy efficiency programs, which can then sell them to generate revenue. All three strategies can be used to fund programs.

States can also opt in to the Clean Energy Incentive Program, which offers early credit for energy efficiency projects in low-income communities during the two years prior to the start of the compliance period. Without this program, projects could not receive credit until the start of the compliance period, currently slated for 2022. For each megawatt-hour of electricity that programs save in 2020 and 2021, eligible low-income energy efficiency programs will get two emission rate credits, or an equivalent number of allowances. Project developers can sell credits to power plant owners, gaining revenue to offset program costs.

Low-income energy efficiency providers should engage with state air agencies to help shape state plans. The Clean Power Plan provides a unique opportunity to drive investment in low-income energy efficiency programs and gives states additional incentive to act.

25 For more information on consumer protections for on-bill financing programs, particularly for low-income households, see Burcat and Power 2013.

26 For properties financed through Low Income Housing Tax Credits (LIHTC), recapitalization windows present approximately every 15 years.

27 Disclosure and benchmarking policies refer to local laws that require owners of commercial and multifamily residential buildings to annually disclose their buildings' energy use and benchmark it relative to other buildings. An energy efficiency resource standard (EERS) establishes specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs. For more information on EERSs, see aceee.org/topics/energy-efficiency-resource-standard-eers.

28 Quantifiable performance indicator (QPI) targets are set by the utility in order to measure how well its performance meets planned strategic goals and objectives. Low-income participation can be included as a QPI in order to make sure that attention to low-income households remains a priority for the utility.

Conclusion



Based on our analysis results, we determined that certain households—namely low-income, low-income multifamily, African-American, Latino, and renters—devote a disproportionate share of their income to energy expenses. Low-income households typically live in less efficient housing and are often more difficult to reach with information about energy efficiency programs.

Many of these households, due to lack of disposable income to invest in energy efficiency measures, have less ability to participate in their utility's energy efficiency programs. In order to overcome the barriers to participation that low-income customers face, governments and utilities should enhance their low-income program offerings, improve program design and implementation for low-income households, and better utilize existing channels and programs that target low-income households. Programs that address high energy burden also help alleviate poverty and provide other benefits to society beyond energy savings, such as economic development, employment, education, and public health.

Utility-led energy efficiency is an underutilized strategy that could complement bill assistance and weatherization programs to alleviate high household energy burdens in low-income communities. Energy efficiency programs in low-income communities need improved design and targeting in order to address long-term energy affordability needs. Local governments and utilities can work together to improve energy efficiency in these communities. We identified several strategies to ramp up energy efficiency, including improving current low-income program offerings, incorporating demographic data into program goals and evaluation, exploring financing options, and using additional policy levers.

This report has focused on improving low-income energy efficiency as a strategy for addressing high energy burdens. While this is an important strategy for reducing household energy use, it will not break cycles of poverty or completely eradicate high utility costs for all households. We estimate that energy efficiency investments (i.e., whole-home retrofits) for low-income households can make homes 25% more efficient than the average home, which means these investments have the potential to reduce the energy burden of a low-income household by nearly 30%.²⁹ Energy efficiency is a big part of the solution, but we still have a long way to go to ensure an equitable distribution of energy costs for all American families.

Due to changing regulatory policies, cities and states have additional urgency to ramp up efforts to increase low-income energy efficiency. In addition to the Clean Power Plan, the EPA has numerous potential rulemakings to limit the emissions of nitrogen oxides, sulfur dioxide, and carbon dioxide, which will increase states' obligations to reduce emissions. Energy efficiency remains a least-cost strategy for states to reduce multipollutant emissions. Under this approach, greater investment in low-income energy efficiency can cut emissions while improving energy affordability for those most in need.

Next Steps and Future Research

We encourage cities and other stakeholder groups to use this report's energy burden data and principles in

their efforts to design and deliver energy efficiency policies and programs targeted toward the alleviation of high energy burdens. Cities can compare their median energy burden with the burdens of the groups in the study (Appendix B) and determine how their city or metro area stacks up regionally and nationally for each group studied (Appendix E). The energy burden data in this report is a snapshot of the current energy burden landscape, and stakeholders should use the data as a baseline for improvement.

While this report focuses on energy burdens in cities, rural communities experience acute energy burdens as well, and the severity of these burdens may differ from those experienced in cities. Although the strategies presented in this report can be applied to rural communities, future research should explore the landscape of rural energy burden and determine the specific policy needs of rural families that experience high energy burdens.

We hope that this report's findings and recommendations will act as conversation starters for cities and states that want to consider new energy affordability measures and determine how best to help their citizens obtain affordable and equitable access to energy. We have found that high energy bills, low household income, inefficient housing stock, and lack of access to efficiency programs contribute to energy burden. Cities and states should explore these drivers to determine why energy burden is higher in some regions and communities than in others.

We estimate that energy efficiency investments (i.e., whole-home retrofits) for low-income households can make homes 25% more efficient than the average home, which means these investments have the potential to reduce the energy burden of a low-income household by nearly 30%.

²⁹ We assume 25% savings from energy efficiency upgrades based on the US Department of Energy's estimate (DOE 2014), and use the values in table 3 to calculate the 30% energy savings. A 30% savings for low-income households would reduce energy costs per square foot to \$1.06, which reduces annual utility spending to \$1,269 and energy burden to 5.1%. This is a reduction of 29.2% from the original energy burden of 7.2%. This savings estimate does not include the net costs for energy efficiency improvements.

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Appendix A. Sample Sizes

Table A1. Sample sizes used in energy burden calculations

City	Data year	All households	Low-income households	Low-income multifamily households	African-American households	Latino households	Renting households
Atlanta	2011	2,564	1,170	291	878	202	835
Austin	2013	2,794	1,178	326	206	692	1,145
Baltimore	2013	2,786	1,084	213	742	126	756
Birmingham	2011	2,876	1,397	212	809	91	717
Boston	2013	2,373	829	183	199	172	732
Charlotte	2011	2,816	1,326	263	716	214	888
Chicago	2013	766	388	128	176	128	288
Cincinnati	2011	2,401	1,141	246	271	66	683
Cleveland	2011	2,708	1,204	168	485	132	679
Columbus	2011	3,009	1,317	243	431	105	1,030
Dallas	2011	2,887	1,280	353	491	669	1,064
Denver	2011	2,714	1,171	354	144	482	884
Detroit	2013	2,530	1,063	186	445	77	628
Fort Worth	2011	3,095	1,435	309	426	671	1,052
Hartford	2013	2,817	1,105	210	252	303	659
Houston	2013	2,527	1,096	319	471	705	910
Indianapolis	2011	3,013	1,314	246	429	176	900
Jacksonville	2013	2,996	1,358	208	606	175	972
Kansas City	2011	2,974	1,430	216	356	164	876
Las Vegas	2013	2,496	1,186	294	284	564	1,112
Los Angeles	2011	3,001	1,773	635	290	1,161	1,591
Louisville	2013	2,916	1,218	204	370	98	822
Memphis	2011	2,870	1,348	220	1,280	119	900
Miami	2013	2,351	1,154	444	445	971	865
Milwaukee	2011	1,911	1,005	309	284	137	785
Minneapolis	2013	2,624	914	170	118	100	517
Nashville	2013	2,919	1,233	238	416	155	921
New Orleans	2011	2,800	1,407	191	901	210	911
New York City	2013	677	353	155	147	131	333
Oklahoma City	2013	3,304	1,310	214	354	319	1,034
Orlando	2013	3,031	1,284	276	444	719	1,101
Philadelphia	2013	2,893	1,322	163	602	215	730
Phoenix	2011	2,569	1,137	264	147	555	873
Pittsburgh	2011	2,758	1,203	128	210	50	642
Portland	2011	2,916	1,256	347	60	209	1,022
Providence	2011	2,666	1,143	110	105	195	672
Richmond	2013	2,916	1,193	189	791	134	868
Riverside	2011	2,816	1,400	216	232	1,105	1,063
Sacramento	2011	2,954	1,422	334	219	472	1,154
San Antonio	2013	3,357	1,499	273	212	1,659	1,142
San Diego	2011	3,123	1,497	498	169	732	1,404
San Francisco	2011	2,878	1,220	469	115	410	1,343
San Jose	2011	3,292	1,374	392	113	658	1,337
Seattle	2013	2,765	1,017	361	142	179	976
St. Louis	2011	2,663	1,224	201	541	71	748
Tampa	2013	2,225	883	211	234	293	680
Virginia Beach	2011	3,018	1,335	278	873	136	1,002
Washington, DC	2013	2,307	670	207	556	226	611
Total	N/A	129,662	57,266	12,665	19,187	17,333	42,857

Appendix B. City Median Energy Burdens

Table B1. Median gross household income and energy burdens for the median household in each group

City	Data year	Median household	Median low-income household	Median low-income multifamily	Median African-American household	Median Latino household	Median renter household
Atlanta	2011	4.97%	10.19%	8.31%	6.60%	6.60%	6.75%
Austin	2013	2.65%	5.47%	4.09%	3.47%	3.72%	3.14%
Baltimore	2013	3.12%	7.14%	4.80%	4.41%	3.29%	3.64%
Birmingham	2011	5.34%	10.92%	8.71%	7.68%	6.55%	7.30%
Boston	2013	2.76%	6.72%	4.40%	3.89%	3.28%	2.86%
Charlotte	2011	4.00%	7.89%	5.50%	5.14%	4.91%	4.78%
Chicago	2013	3.05%	6.73%	5.57%	6.56%	3.64%	4.12%
Cincinnati	2011	4.34%	8.45%	6.19%	6.86%	3.87%	5.96%
Cleveland	2011	4.22%	8.47%	5.36%	7.00%	4.64%	5.47%
Columbus	2011	3.95%	8.13%	6.52%	6.19%	5.00%	5.17%
Dallas	2011	4.25%	8.84%	6.51%	5.45%	5.97%	4.73%
Denver	2011	3.20%	6.59%	5.43%	4.81%	4.54%	4.18%
Detroit	2013	3.52%	7.98%	5.26%	5.78%	5.72%	4.56%
Fort Worth	2011	4.36%	8.02%	6.12%	5.24%	5.72%	5.04%
Hartford	2013	3.74%	8.16%	5.90%	6.03%	5.20%	4.92%
Houston	2013	3.24%	6.94%	5.22%	3.96%	3.81%	3.49%
Indianapolis	2011	3.70%	7.66%	6.51%	5.40%	4.13%	5.00%
Jacksonville	2013	3.87%	7.64%	5.56%	5.30%	4.33%	4.41%
Kansas City	2011	4.48%	8.49%	6.36%	7.91%	6.64%	6.11%
Las Vegas	2013	3.49%	6.11%	4.51%	4.08%	4.42%	3.71%
Los Angeles	2011	2.75%	4.60%	3.48%	3.72%	3.27%	2.73%
Louisville	2013	3.57%	7.60%	6.10%	4.66%	4.16%	4.77%
Memphis	2011	6.15%	13.22%	10.88%	9.65%	8.26%	8.64%
Miami	2013	3.32%	6.23%	4.80%	4.10%	3.73%	3.80%
Milwaukee	2011	4.08%	7.02%	5.54%	7.40%	4.46%	4.93%
Minneapolis	2013	2.32%	5.11%	3.05%	4.14%	3.14%	2.57%
Nashville	2013	3.11%	6.40%	5.18%	4.21%	4.45%	3.76%
New Orleans	2011	5.25%	9.79%	6.93%	8.06%	5.07%	6.31%
New York City	2013	3.67%	6.78%	5.68%	4.37%	4.87%	3.75%
Oklahoma City	2013	3.51%	7.36%	5.21%	4.98%	4.26%	4.27%
Orlando	2013	3.93%	7.55%	6.24%	5.27%	4.85%	4.14%
Philadelphia	2013	3.82%	8.82%	5.12%	6.46%	7.30%	4.70%
Phoenix	2011	4.18%	7.92%	6.09%	4.93%	6.00%	5.30%
Pittsburgh	2011	4.52%	9.42%	7.08%	8.31%	4.95%	6.00%
Portland	2011	2.81%	5.22%	4.16%	3.99%	3.53%	3.34%
Providence	2011	4.66%	9.46%	7.10%	6.03%	7.33%	6.18%
Richmond	2013	3.10%	6.54%	5.17%	4.24%	3.49%	3.97%
Riverside	2011	3.54%	5.74%	4.22%	3.81%	3.77%	4.14%
Sacramento	2011	2.93%	5.29%	3.60%	4.49%	3.45%	3.41%
San Antonio	2013	3.77%	7.80%	5.00%	3.99%	4.50%	3.95%
San Diego	2011	2.30%	3.90%	2.66%	2.24%	2.54%	2.27%
San Francisco	2011	1.41%	2.82%	1.89%	2.27%	1.83%	1.27%
San Jose	2011	1.78%	3.82%	2.28%	1.86%	2.35%	1.73%
Seattle	2013	2.05%	4.59%	3.08%	2.84%	2.22%	2.18%
St. Louis	2011	4.07%	8.37%	6.25%	7.40%	4.21%	5.90%
Tampa	2013	3.32%	7.28%	5.95%	3.97%	3.91%	3.64%
Virginia Beach	2011	3.85%	7.46%	5.39%	4.98%	3.75%	4.54%
Washington, DC	2013	2.12%	6.11%	4.28%	2.88%	2.67%	2.44%

Appendix C. Energy Burdens at the Median and Highest Energy Burden Quartile, by City

Table C1. Energy burdens for low-income and multifamily low-income households

City	Data year	Median household	Median low-income household	Highest energy burden quartile for low-income households	Median low-income multifamily household	Highest energy burden quartile for low-income multifamily households
Atlanta	2011	4.97%	10.19%	18.24%	8.31%	15.72%
Austin	2013	2.65%	5.47%	9.73%	4.09%	7.29%
Baltimore	2013	3.12%	7.14%	13.65%	4.80%	9.54%
Birmingham	2011	5.34%	10.92%	18.82%	8.71%	16.17%
Boston	2013	2.76%	6.72%	12.36%	4.40%	8.94%
Charlotte	2011	4.00%	7.89%	14.45%	5.50%	10.22%
Chicago	2013	3.05%	6.73%	13.41%	5.57%	14.59%
Cincinnati	2011	4.34%	8.45%	15.49%	6.19%	12.95%
Cleveland	2011	4.22%	8.47%	14.07%	5.36%	12.31%
Columbus	2011	3.95%	8.13%	12.93%	6.52%	11.17%
Dallas	2011	4.25%	8.84%	14.50%	6.51%	11.28%
Denver	2011	3.20%	6.59%	10.57%	5.43%	8.79%
Detroit	2013	3.52%	7.98%	15.26%	5.26%	9.76%
Fort Worth	2011	4.36%	8.02%	13.02%	6.12%	11.35%
Hartford	2013	3.74%	8.16%	14.49%	5.90%	11.75%
Houston	2013	3.24%	6.94%	11.84%	5.22%	9.18%
Indianapolis	2011	3.70%	7.66%	12.83%	6.51%	9.91%
Jacksonville	2013	3.87%	7.64%	13.48%	5.56%	9.06%
Kansas City	2011	4.48%	8.49%	14.60%	6.36%	11.08%
Las Vegas	2013	3.49%	6.11%	10.39%	4.51%	7.55%
Los Angeles	2011	2.75%	4.60%	8.84%	3.48%	6.67%
Louisville	2013	3.57%	7.60%	12.74%	6.10%	10.42%
Memphis	2011	6.15%	13.22%	25.47%	10.88%	21.73%
Miami	2013	3.32%	6.23%	11.04%	4.80%	7.99%
Milwaukee	2011	4.08%	7.02%	12.52%	5.54%	9.65%
Minneapolis	2013	2.32%	5.11%	8.20%	3.05%	5.77%
Nashville	2013	3.11%	6.40%	10.91%	5.18%	9.40%
New Orleans	2011	5.25%	9.79%	18.90%	6.93%	10.43%
New York City	2013	3.67%	6.78%	14.01%	5.68%	9.97%
Oklahoma City	2013	3.51%	7.36%	12.56%	5.21%	9.03%
Orlando	2013	3.93%	7.55%	11.51%	6.24%	9.39%
Philadelphia	2013	3.82%	8.82%	16.67%	5.12%	9.07%
Phoenix	2011	4.18%	7.92%	13.42%	6.09%	9.79%
Pittsburgh	2011	4.52%	9.42%	15.67%	7.08%	15.72%
Portland	2011	2.81%	5.22%	8.76%	4.16%	6.53%
Providence	2011	4.66%	9.46%	16.66%	7.10%	11.07%
Richmond	2013	3.10%	6.54%	11.51%	5.17%	9.26%
Riverside	2011	3.54%	5.74%	9.50%	4.22%	7.19%
Sacramento	2011	2.93%	5.29%	8.74%	3.60%	6.35%
San Antonio	2013	3.77%	7.80%	14.06%	5.00%	9.16%
San Diego	2011	2.30%	3.90%	6.74%	2.66%	4.80%
San Francisco	2011	1.41%	2.82%	5.24%	1.89%	3.26%
San Jose	2011	1.78%	3.82%	6.67%	2.28%	4.05%
Seattle	2013	2.05%	4.59%	8.05%	3.08%	5.61%
St. Louis	2011	4.07%	8.37%	14.78%	6.25%	12.87%
Tampa	2013	3.32%	7.28%	12.13%	5.95%	9.54%
Virginia Beach	2011	3.85%	7.46%	12.61%	5.39%	9.67%
Washington, DC	2013	2.12%	6.11%	11.70%	4.28%	7.68%

Table C2. Energy burdens for African-American and Latino households

City	Data year	Median household	Median African-American household	Highest energy burden quartile for African-American households	Median Latino household	Highest energy burden quartile for Latino households
Atlanta	2011	4.97%	6.60%	12.32%	6.60%	11.53%
Austin	2013	2.65%	3.47%	6.11%	3.72%	6.75%
Baltimore	2013	3.12%	4.41%	8.92%	3.29%	5.66%
Birmingham	2011	5.34%	7.68%	15.44%	6.55%	10.44%
Boston	2013	2.76%	3.89%	6.38%	3.28%	6.22%
Charlotte	2011	4.00%	5.14%	10.85%	4.91%	8.90%
Chicago	2013	3.05%	6.56%	15.27%	3.64%	7.14%
Cincinnati	2011	4.34%	6.86%	15.64%	3.87%	7.26%
Cleveland	2011	4.22%	7.00%	13.14%	4.64%	9.77%
Columbus	2011	3.95%	6.19%	10.93%	5.00%	9.56%
Dallas	2011	4.25%	5.45%	10.61%	5.97%	10.06%
Denver	2011	3.20%	4.81%	9.39%	4.54%	8.70%
Detroit	2013	3.52%	5.78%	14.78%	5.72%	10.19%
Fort Worth	2011	4.36%	5.24%	10.27%	5.72%	9.07%
Hartford	2013	3.74%	6.03%	12.47%	5.20%	11.10%
Houston	2013	3.24%	3.96%	8.56%	3.81%	6.87%
Indianapolis	2011	3.70%	5.40%	10.07%	4.13%	7.57%
Jacksonville	2013	3.87%	5.30%	10.06%	4.33%	6.68%
Kansas City	2011	4.48%	7.91%	16.22%	6.64%	11.96%
Las Vegas	2013	3.49%	4.08%	8.04%	4.42%	7.09%
Los Angeles	2011	2.75%	3.72%	9.47%	3.27%	6.38%
Louisville	2013	3.57%	4.66%	8.59%	4.16%	9.10%
Memphis	2011	6.15%	9.65%	19.36%	8.26%	15.93%
Miami	2013	3.32%	4.10%	8.63%	3.73%	6.36%
Milwaukee	2011	4.08%	7.40%	15.48%	4.46%	7.92%
Minneapolis	2013	2.32%	4.14%	7.90%	3.14%	6.10%
Nashville	2013	3.11%	4.21%	9.21%	4.45%	7.81%
New Orleans	2011	5.25%	8.06%	16.38%	5.07%	8.23%
New York City	2013	3.67%	4.37%	9.00%	4.87%	8.90%
Oklahoma City	2013	3.51%	4.98%	9.14%	4.26%	7.40%
Orlando	2013	3.93%	5.27%	8.53%	4.85%	7.55%
Philadelphia	2013	3.82%	6.46%	14.23%	7.30%	15.74%
Phoenix	2011	4.18%	4.93%	8.61%	6.00%	10.74%
Pittsburgh	2011	4.52%	8.31%	16.14%	4.95%	12.44%
Portland	2011	2.81%	3.99%	10.61%	3.53%	6.87%
Providence	2011	4.66%	6.03%	12.90%	7.33%	11.66%
Richmond	2013	3.10%	4.24%	7.99%	3.49%	6.28%
Riverside	2011	3.54%	3.81%	7.30%	3.77%	6.01%
Sacramento	2011	2.93%	4.49%	8.14%	3.45%	5.98%
San Antonio	2013	3.77%	3.99%	7.96%	4.50%	8.60%
San Diego	2011	2.30%	2.24%	4.29%	2.54%	4.40%
San Francisco	2011	1.41%	2.27%	4.22%	1.83%	3.33%
San Jose	2011	1.78%	1.86%	3.93%	2.35%	4.33%
Seattle	2013	2.05%	2.84%	6.08%	2.22%	4.65%
St. Louis	2011	4.07%	7.40%	14.41%	4.21%	7.32%
Tampa	2013	3.32%	3.97%	8.05%	3.91%	6.44%
Virginia Beach	2011	3.85%	4.98%	9.64%	3.75%	6.08%
Washington, DC	2013	2.12%	2.88%	5.78%	2.67%	4.57%

Table C3. Energy burdens for renting households

City	Data year	Median household	Median renting household	Highest energy burden quartile for renting households
Atlanta	2011	4.97%	6.75%	13.25%
Austin	2013	2.65%	3.14%	5.65%
Baltimore	2013	3.12%	3.64%	7.41%
Birmingham	2011	5.34%	7.30%	15.06%
Boston	2013	2.76%	2.86%	5.76%
Charlotte	2011	4.00%	4.78%	9.65%
Chicago	2013	3.05%	4.12%	10.01%
Cincinnati	2011	4.34%	5.96%	12.12%
Cleveland	2011	4.22%	5.47%	11.93%
Columbus	2011	3.95%	5.17%	9.82%
Dallas	2011	4.25%	4.73%	9.07%
Denver	2011	3.20%	4.18%	7.77%
Detroit	2013	3.52%	4.56%	10.20%
Fort Worth	2011	4.36%	5.04%	8.70%
Hartford	2013	3.74%	4.92%	10.24%
Houston	2013	3.24%	3.49%	6.83%
Indianapolis	2011	3.70%	5.00%	9.43%
Jacksonville	2013	3.87%	4.41%	8.21%
Kansas City	2011	4.48%	6.11%	11.68%
Las Vegas	2013	3.49%	3.71%	6.82%
Los Angeles	2011	2.75%	2.73%	5.97%
Louisville	2013	3.57%	4.77%	9.25%
Memphis	2011	6.15%	8.64%	18.48%
Miami	2013	3.32%	3.80%	6.62%
Milwaukee	2011	4.08%	4.93%	9.85%
Minneapolis	2013	2.32%	2.57%	5.52%
Nashville	2013	3.11%	3.76%	6.99%
New Orleans	2011	5.25%	6.31%	12.61%
New York City	2013	3.67%	3.75%	7.19%
Oklahoma City	2013	3.51%	4.27%	7.97%
Orlando	2013	3.93%	4.14%	7.90%
Philadelphia	2013	3.82%	4.70%	11.18%
Phoenix	2011	4.18%	5.30%	9.11%
Pittsburgh	2011	4.52%	6.00%	11.87%
Portland	2011	2.81%	3.34%	5.85%
Providence	2011	4.66%	6.18%	11.74%
Richmond	2013	3.10%	3.97%	7.03%
Riverside	2011	3.54%	4.14%	7.30%
Sacramento	2011	2.93%	3.41%	6.39%
San Antonio	2013	3.77%	3.95%	7.52%
San Diego	2011	2.30%	2.27%	4.03%
San Francisco	2011	1.41%	1.27%	2.50%
San Jose	2011	1.78%	1.73%	3.45%
Seattle	2013	2.05%	2.18%	4.25%
St. Louis	2011	4.07%	5.90%	12.93%
Tampa	2013	3.32%	3.64%	6.77%
Virginia Beach	2011	3.85%	4.54%	8.52%
Washington, DC	2013	2.12%	2.44%	5.22%

Appendix D. Households with Energy Burden At Least Twice the City Median

Table D1. Percentage of households in each group with energy burdens over two times the city median energy burden

City	Data year	All households	Low-income households	Low-income multifamily households	African-American households	Latino households	Renting households
Atlanta	2011	24.18%	51.45%	41.24%	32.57%	34.65%	33.77%
Austin	2013	23.55%	53.14%	36.81%	33.01%	34.68%	28.82%
Baltimore	2013	23.80%	56.83%	37.09%	36.12%	19.84%	28.84%
Birmingham	2011	25.31%	51.32%	41.51%	38.32%	23.08%	36.82%
Boston	2013	23.98%	50.54%	42.62%	30.65%	26.16%	25.82%
Charlotte	2011	23.76%	49.47%	32.70%	32.40%	29.44%	30.41%
Chicago	2013	29.11%	56.44%	48.44%	52.84%	28.13%	37.85%
Cincinnati	2011	24.32%	48.29%	36.99%	41.70%	22.73%	35.43%
Cleveland	2011	22.97%	50.08%	34.52%	41.03%	28.79%	36.38%
Columbus	2011	23.20%	51.40%	39.51%	40.37%	30.48%	32.43%
Dallas	2011	23.93%	52.19%	39.38%	33.60%	33.18%	27.16%
Denver	2011	23.25%	51.84%	40.40%	40.28%	35.27%	32.13%
Detroit	2013	25.26%	57.10%	36.02%	44.49%	38.96%	34.71%
Fort Worth	2011	21.55%	45.30%	33.33%	30.75%	27.57%	24.90%
Hartford	2013	22.97%	54.30%	38.57%	40.48%	37.29%	34.90%
Houston	2013	24.10%	53.28%	38.87%	34.39%	26.24%	26.37%
Indianapolis	2011	23.76%	52.82%	41.46%	34.97%	26.70%	34.00%
Jacksonville	2013	22.53%	48.97%	30.29%	33.50%	20.57%	26.54%
Kansas City	2011	22.66%	46.50%	34.72%	44.66%	34.15%	33.79%
Las Vegas	2013	20.95%	42.50%	27.89%	30.99%	25.71%	24.64%
Los Angeles	2011	26.22%	42.92%	32.44%	40.34%	30.15%	27.72%
Louisville	2013	22.98%	53.28%	41.67%	31.89%	30.61%	33.33%
Memphis	2011	26.10%	54.15%	43.64%	40.00%	32.77%	37.67%
Miami	2013	23.05%	46.10%	31.08%	32.36%	22.76%	24.74%
Milwaukee	2011	23.81%	43.08%	30.74%	46.13%	24.09%	30.19%
Minneapolis	2013	20.54%	56.46%	31.76%	46.61%	34.00%	29.01%
Nashville	2013	22.82%	52.23%	41.18%	34.38%	34.84%	29.21%
New Orleans	2011	23.71%	45.84%	24.08%	39.62%	17.14%	29.20%
New York City	2013	27.03%	47.03%	36.13%	29.25%	28.24%	24.62%
Oklahoma City	2013	22.19%	52.90%	36.92%	33.62%	26.96%	29.21%
Orlando	2013	20.59%	47.12%	34.42%	29.28%	22.95%	25.25%
Philadelphia	2013	27.03%	56.88%	31.29%	43.52%	47.44%	35.07%
Phoenix	2011	21.37%	46.53%	31.82%	25.85%	34.77%	28.29%
Pittsburgh	2011	23.57%	52.45%	40.63%	45.24%	34.00%	33.18%
Portland	2011	20.71%	45.86%	32.28%	40.00%	31.58%	26.91%
Providence	2011	22.66%	50.83%	34.55%	30.48%	38.46%	33.04%
Richmond	2013	22.53%	53.39%	39.68%	32.24%	25.37%	29.84%
Riverside	2011	20.10%	38.57%	25.93%	25.86%	20.45%	26.06%
Sacramento	2011	22.58%	43.74%	28.74%	36.53%	26.06%	29.12%
San Antonio	2013	24.13%	51.97%	31.14%	26.42%	29.42%	24.78%
San Diego	2011	21.07%	40.88%	26.10%	21.89%	23.91%	20.73%
San Francisco	2011	23.45%	49.92%	30.70%	40.00%	29.27%	21.67%
San Jose	2011	24.30%	53.78%	31.38%	28.32%	32.67%	24.61%
Seattle	2013	23.33%	55.36%	38.23%	38.03%	28.49%	26.33%
St. Louis	2011	24.30%	51.80%	38.81%	46.03%	19.72%	38.77%
Tampa	2013	22.47%	54.47%	41.23%	29.06%	23.55%	25.44%
Virginia Beach	2011	22.27%	48.39%	32.73%	32.42%	19.85%	28.34%
Washington, DC	2013	22.71%	68.06%	50.24%	32.91%	28.32%	29.30%

Appendix E. Regional Energy Burden

FIGURE E1. Energy burden for median household from select groups in Southeast cities, ordered from highest to lowest based on the average of the median energy burdens across all groups.

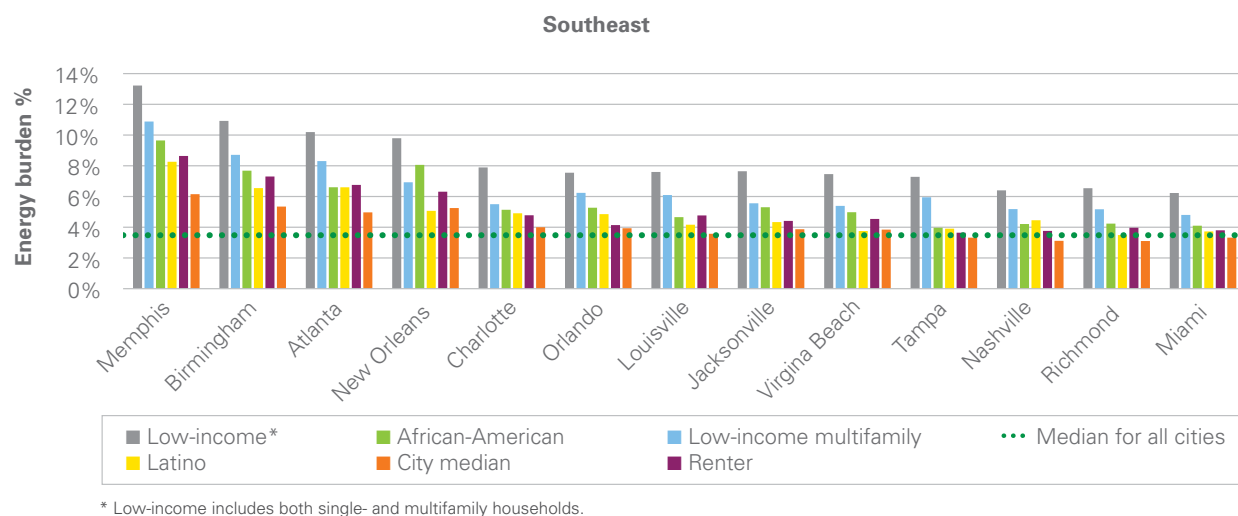


Figure E2. Energy burden for median household from select groups in Midwest cities, ordered from highest to lowest based on the average of the median energy burdens across all groups.

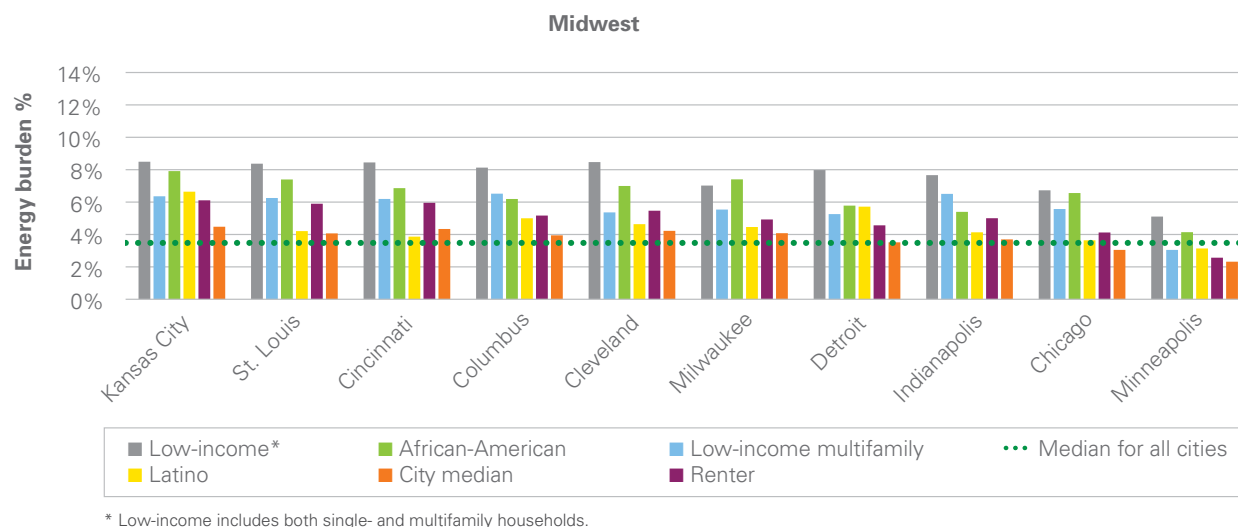


FIGURE E3. Energy burden for median household from select groups in Northeast cities, ordered from highest to lowest based on the average of the median energy burdens across all groups.

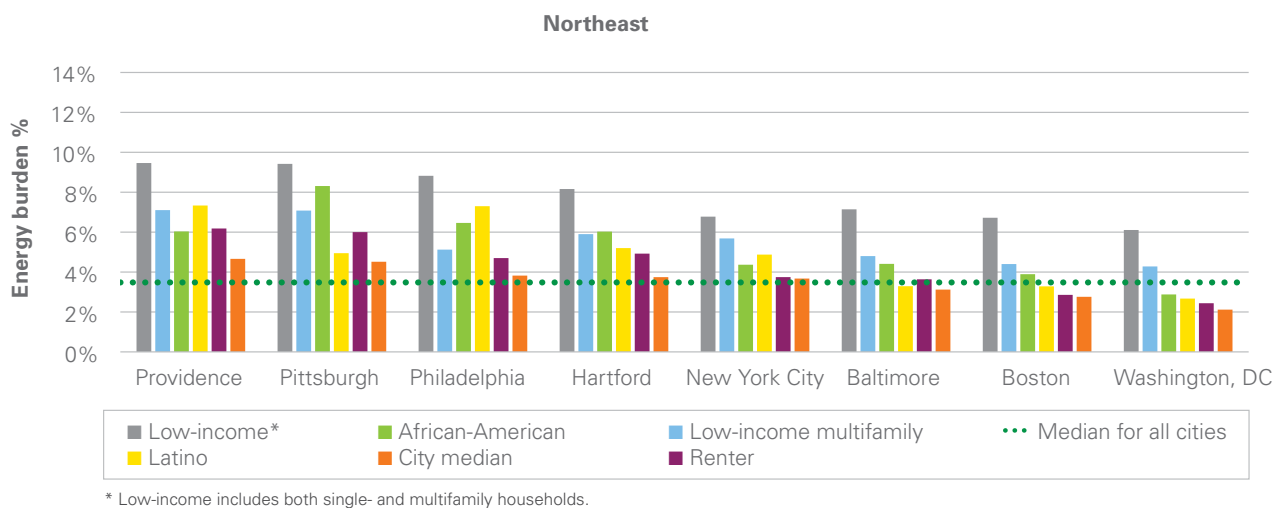


Figure E4. Energy burden for median household from select groups in South Central cities, ordered from highest to lowest based on the average of the median energy burdens across all groups.

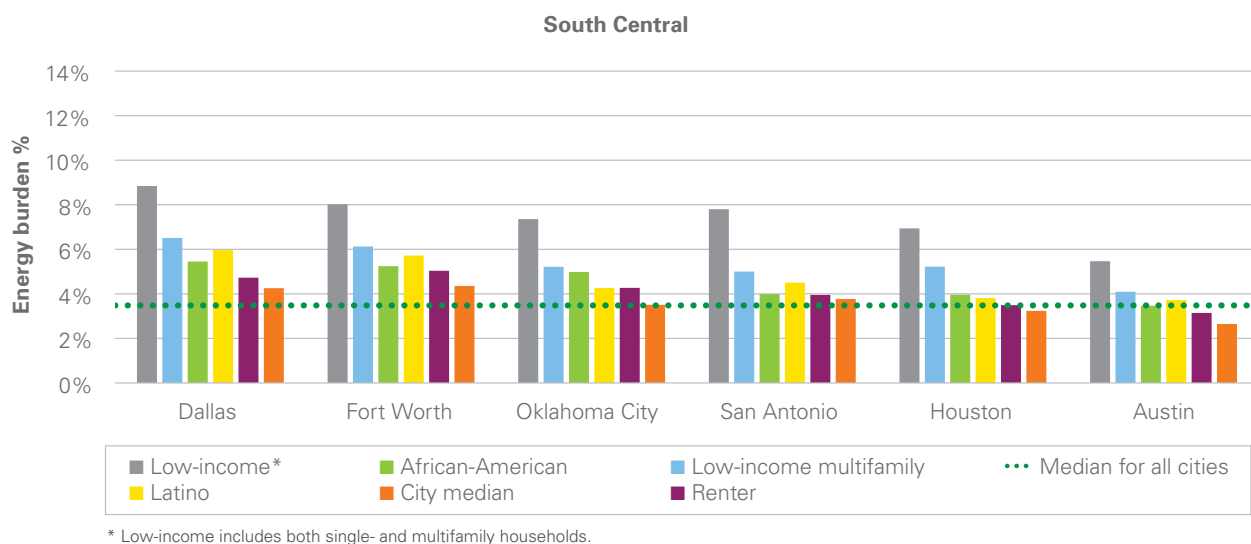


FIGURE E5. Energy burden for median household from select groups in Southwest cities, ordered from highest to lowest based on the average of the median energy burdens across all groups.

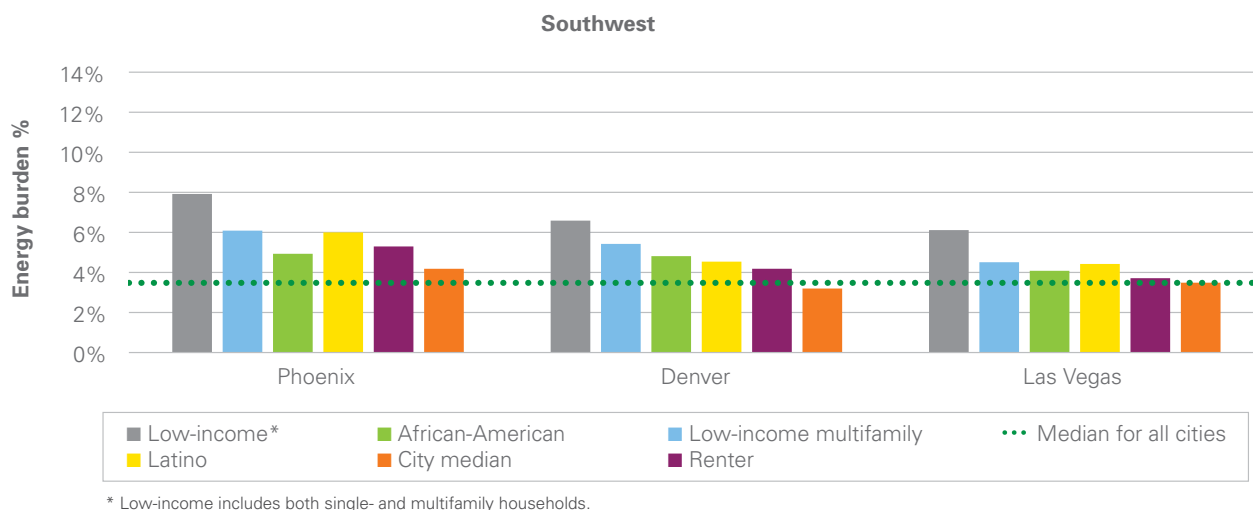


FIGURE E6. Energy burden for median household from select groups in Northwest cities, ordered from highest to lowest based on the average of the median energy burdens across all groups.

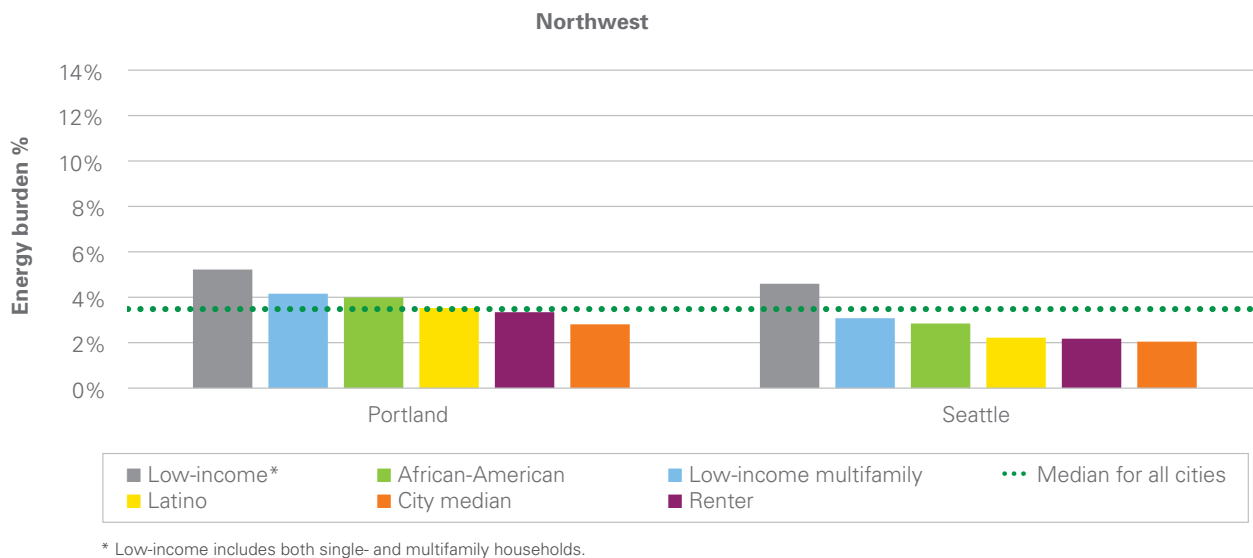
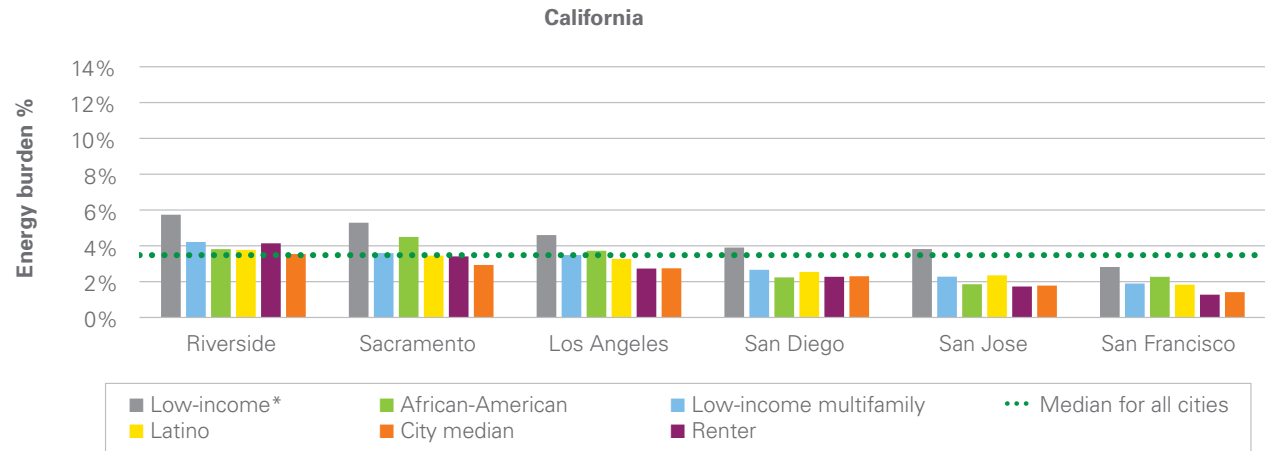


FIGURE E7. Energy burden for median household from select groups in California cities, ordered from highest to lowest based on the average of the median energy burdens across all groups.

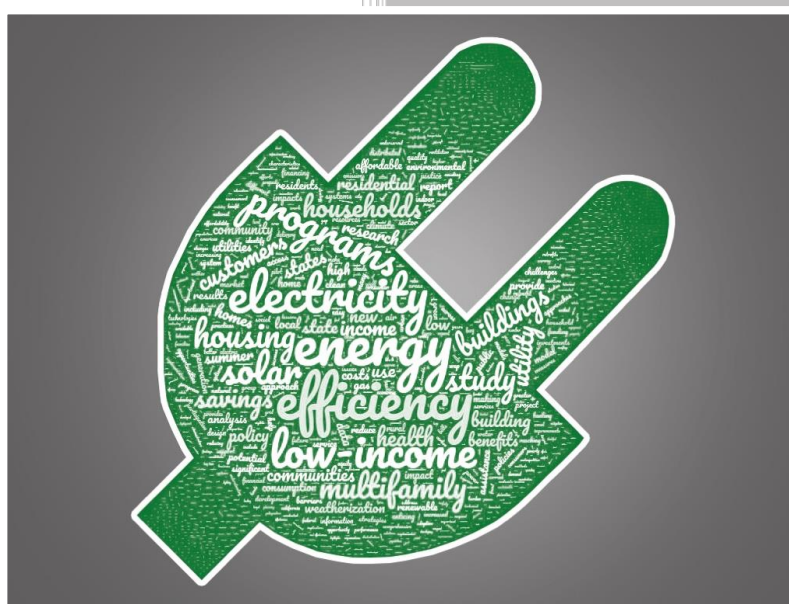


* Low-income includes both single- and multifamily households.



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Low-Income Energy Affordability: Conclusions from a Literature Review



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Date: March 2020

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Energy & Transportation Science Division

**LOW-INCOME ENERGY AFFORDABILITY:
CONCLUSIONS FROM A LITERATURE REVIEW**

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ACRONYMS

AMI	Area Median Income
ARRA	American Recovery and Reinvestment Act
CDC	Center for Disease Control
DOE	U.S. Department of Energy
EECLP	Energy Efficiency and Conservation Loan Program
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EV	Electric Vehicles
FERC	Federal Energy Regulatory Commission
FPL	Federal Poverty Level
HHS	U.S. Department of Health and Human Services
HUD	U.S. Department of Housing and Urban Development
IRP	Integrated Resource Plan
LIHEAP	Low Income Home Energy Assistance Program
LIHTA	Low-Income Housing Tax Credit Program
MSA	Metropolitan Statistical Area
MOU	Memorandum of Understanding
NASCSP	National Association of State Community Services Programs
NGO	Non-governmental organization
NCHH	National Center for Healthy Housing
NREL	National Renewable Energy Laboratory
ORNL	Oak Ridge National Laboratory
RECS	Residential Energy Consumption Survey
RGGI	Regional Greenhouse Gas Initiative
SDG	Sustainable Cities and Communities
SEP	State Energy Program
SMI	State Median Income
SPM	Supplemental Poverty Measure
UNDP	U.S. Development Program
USDA	U.S. Department of Agriculture
TVA	Tennessee Valley Authority
WAP	Weatherization Assistance Program

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ABSTRACT

This paper examines the persistent problem of high energy burdens among low-income households, based on a review of more than 180 publications that pointed to several promising opportunities to address energy affordability including inclusive solar programs, leveraged health care benefits, and behavioral economics. using an equity and affordability lens. Even after decades of weatherization and bill-payment programs, low-income households, on average, continue to spend a higher share of their income on electricity and natural gas bills than any other income group. Energy burden for low-income households is not declining, and it remains persistently high, particularly in the South, in rural America, among minority households, and those with children and elderly residents. On a per household basis, utility companies spend less on energy-efficiency programs for low-income households than for other income groups. In addition, government and utility programs that promote rooftop solar power, electric vehicles, and home energy storage are largely inaccessible to low-income households. Our review identifies promising opportunities to address energy affordability including inclusive solar programs, leveraged health care benefits, behavioral economics, data analytics, advanced information and communication technologies, and grid resiliency. Scalable approaches require linking implementing agencies, programs and policies to tackle the complex web of causes and impacts on low-income households with high energy burdens.

1. INTRODUCTION: GOALS, SCOPE, AND STRUCTURE OF LITERATURE REVIEW

1.1 GOALS OF THE LITERATURE REVIEW

Energy drives the U.S. economy and impacts nearly every dimension of modern society; it is an imperative of daily existence. When access to energy becomes difficult, the burden is felt in every facet of life – housing, mobility, health, work, education, and much more.

Since the 1970's introduction of major low-income energy programs in the U.S., the nature of household energy consumption has evolved. For decades, the energy consumed by a typical household increased as suburbanization and sprawl enabled homes to grow, and affluence and innovation made central heating and cooling systems almost universal. Appliances multiplied, and “plug loads” proliferated with the creation of new low-voltage AC devices: computers, telephones, hi-fi's and more (Nordman and Sanchez, 2006). In contrast, low-income households continued to occupy much of the energy inefficient housing stock in the older core of American cities.

Over time, these trends have evolved. Increasingly congested urban areas have motivated moves back to inner cities, re-densifying and gentrifying older neighbourhoods, sometimes at the expense of affordable housing. This has created a new geography of suburban poverty with issues of energy affordability that have not yet been documented. At the same time, many low-income households in rural communities have chosen to maintain their social networks and ways of life, and have not moved to urban areas where jobs and property values have been growing more rapidly. In rural areas where the economy has been stagnant and the housing stock is older, low-income energy burdens are worsening.

Nationwide, innovations continued to transform home energy use, with more efficient appliances (furnaces and heat pumps, refrigerators, etc.), smart thermostats, solid state lighting, low-emissivity windows, and foam insulation – reducing the energy consumed by individual households. Rooftop solar panels have reached “grid parity” in some parts of the U.S.¹, and soon home energy storage systems and electric vehicles (EVs) will enable households to arbitrage their energy assets.

In the midst of these transformations, it is time to review what we know about the energy burden of low-income households:

- How have low-income energy burdens changed over the past decade?
- How have they been affected by energy programs, policies, and technology trends?
- What opportunities offer the greatest promise to reduce the energy burden of low-income households, as the U.S. continues its transition to a more efficient and renewable energy system?

To answer these questions, we summarize the knowledge embodied in the last decade of literature focused on low-income energy burdens in the U.S. Many entities across the U.S. – chiefly utilities and federal and state agencies, but also nonprofits and religious organizations, as well as cities and community organizations – work to save energy and reduce the energy costs of

¹ <https://www.greentechmedia.com/articles/read/gtm-research-20-us-states-at-grid-parity-for-residential-solar#gs.7enug2>

low-income households. As a result, a substantial body of literature has examined the design and impacts of these programs and policies. Other research has produced energy-focused case studies of low-income communities, surveys of the energy behavior of low-income households, and accounts of energy bills in the overall expenditures of low-income households. With the proliferation of information on the internet, this decade of literature is immense. Our literature search methodology is described in Section 1.3.

This paper begins by characterizing the magnitude, causes, and impacts of the energy burden currently experienced by low-income households in the U.S. It then describes the multiplicity of energy programs and policies that impact low-income energy burdens. Program design, implementation, participation rates, and investment levels are described in Section 3. This is followed by a summary of the cost-effectiveness and impacts of the programs, which enables estimates of the remaining potential in Section 4. Attention then turns to identifying major gaps and opportunities that energy programs and policies could address in the future (Section 5), and we end with conclusions about opportunities to scale up these impacts.

1.2 THE ENERGY EQUITY LENS

Increasingly energy scholars are focusing on the importance of equity in the transition to a smarter and greener energy economy. The rapid uptake of new technologies has the potential to benefit some and harm others, to the extent that resources, jobs, and capital are redistributed. Depending on the sources and distribution of financing, the design of policies and programs, and the location of infrastructure and facility investments, low-income households may benefit or lose going forward. And if low-income households “lose,” all households lose, because there will be negative effects for all Americans if segments of society are left behind. Overall, the U.S. is experiencing a growing wealth disparity between low-income households and more affluent Americans (Curti, Andersen, and Wright, 2018). Living in communities of color, indigenous populations, and immigrants typically means more limited access to resources. This intersection of race, ethnicity, and class needs to be considered when designing effective low-income energy programs and policies (Reames, 2016; Sunter, Castellanos, and Kammen, 2019).

The environmental justice community has highlighted equity issues in the debate about environmental externalities from the consumption of energy. Due to their lower per capita energy consumption, low-income households contribute proportionately less to local and global air pollution. At the same time, they tend to suffer disproportionately more from the impacts of poor air quality (National Research Council, 2010a, b). These past trends highlight the possibility that the transition to increasing use of renewable energy underway for many states and communities could cause energy justice to unfold in similarly inequitable ways because of long-standing and uneven power dynamics (Healy and Barry, 2017). Equity is increasingly being considered in discussions of energy program design (Curti et al., 2018; Massetti et al., 2017). The literature on environmental equity concerns have enumerated energy policy linkages to health outcomes, access to cleaner air, transportation and other public services which contribute to households’ overall well-being (Jenkins et al., 2016; Massetti et al., 2017). In addition, researchers also recognize that policies to decarbonize the energy sector, can, in fact, worsen disparities due to their disproportionate effects on economically weaker segments of society (Monyei et al., 2019).

Formal discussions of equity typically distinguish between procedural equity that deals with “inclusion” and distributive equity that deals with “access” (Curti et al., 2018). In addition, this

paper also considers intergenerational equity as an important dimension of energy affordability. Each of these dimensions is discussed below in the context of low-income energy programs. Additional dimensions often refer to redistributive equity (fairness in the punishment of wrongs), structural equity (prevention of the chronic, cumulative disadvantage experienced by subordinated groups), and transgenerational equity (avoidance of unfair burdens on future generations) (Franklin and Osborne, 2017).

1.2.1 Procedural Equity (Inclusion)

Procedural equity is the idea of fairness and transparency of the processes that allocate resources and adjudicate disputes. Connected to the desire for due process, one aspect of procedural equity is related to administrative and legal proceedings. In some instances, courts of law have demanded an equitable distribution of resources. As one example, a court settlement of an EPA case against the Tennessee Valley Authority involving air pollution violations involved the creation of an energy-efficiency program for low-income customers.² The idea of procedural equity can also be applied to non-legal contexts in which some process is employed to resolve conflict or divide benefits or burdens. Others emphasize “inclusion” as a key component of procedural equity: “inclusive, accessible, authentic engagement and representation in the process to develop or implement programs or policies” (Curti et al., 2018, p. 9).

Economically disadvantaged communities across the country are amplifying their voices to ensure that the transition to increasing use of energy efficiency and renewable energy considers their needs. For example, Goldberg and McKibbin (2018) describe how the Future Energy Jobs Act in Illinois materialized with the help of a coalition of interest groups, increasing investment in energy efficiency and targeting economically disadvantaged communities. Similarly, advocates from the environmental, affordable housing, energy, and low-income communities in Pennsylvania organized a collaborative advocacy that drove improvements to low-income energy-efficiency policy across the State. Their work drew on the skills, expertise, and resources of multiple disciplines, and prioritized the multiple benefits that energy efficiency provides for low-income households (Grevatt et al., 2018).

1.2.2 Distributive Equity (Access)

Distributive equity refers to fairness in the distribution of rights or resources. In his *Theory of Justice*, John Rawls (1971) claims that one's place of birth, social status, and family influences are matters of luck that should not unduly influence the amount of benefits we receive in life. The goal of distributive equity is to limit the influence of luck so that goods are distributed more fairly and to everyone's advantage. This line of reasoning has been extended by many to argue that distributive equity is achieved when programs and policies result in fair distributions of benefits and burdens across all segments of a community, prioritizing those with highest need (Curti et al., 2018, p. 9).

Across the country, energy-efficiency programs, special rates for electric vehicles, and net metering of solar rooftop installations are paid for in part with low-income ratepayer funds, but do not provide commensurate benefits to low-income ratepayers who do not have the resources to take advantage of these programs. If the energy industry, government agencies, NGOs and

²https://www.tva.gov/file_source/TVA/Site%20Content/Environment/Environmental%20Stewardship/Air%20Quality/EPA%20Mitigation%20Projects/Smart%20Communities%20-%20Extreme%20Energy%20Makeovers%20FAQ.pdf

nonprofits do not address these unintentional consequences, low-income households will continue to suffer disproportionately from high energy burdens, failing most tests of distributive equity (Chant and Huessy, 2018). Carley et al. (2018) also draw the same conclusion based on their assessment of disparities in vulnerability across U.S. counties using the renewable portfolio standard.

1.2.3 Intergenerational Equity

Intergenerational equity adds a time dimension to the equity discussion by considering community obligations to future generations. Actions that serve to increase rather than limit the development options of future generations can be said to improve intergenerational equity (Norton, 2005). In the field of clean energy, intergenerational equity frequently involves deliberating which aspects of the present should be maintained or changed for future generations. Most energy efficiency and renewable energy programs reduce CO₂ emissions and, as a result, contribute positively to intergenerational equity in some ways. How these programs may impact the social and economic contours of communities across generations has received much less emphasis.

1.3 THE CONTEXT: MULTIPLE STAKEHOLDERS IN THE LOW-INCOME HOUSING MARKET

Numerous decision-makers and stakeholders influence the energy efficiency and renewable energy consumption of low-income housing (Figure 1.1). This highly fragmented affordable housing market challenges efforts to improve low-income energy affordability. Government agencies have administrative and regulatory roles that influence each of these stakeholders to varying degrees. In terms of word counts, energy utilities are mentioned most often in the abstracts of the 183 publications examined in this review. Local non-governmental organizations (NGOs) and community-based groups are also key stakeholders based on this tally. At the other extreme, the terms “building manager” and “property manager” do not appear in the 183 abstracts, and “landlord” and “property owner” are mentioned only 10 times, indicating that these stakeholders have received limited analysis in this body of literature. While the literature describes the landlord/tenant split incentive and the difference between renter and homeowner investments in energy-efficiency, there is little analysis of the nature of landlords operating in the low-income housing market, despite our assessment of the influential roles they play. Figure 1.1 provides a framework for understanding how current programs and policies operate and how they can be leveraged to provide a more effective and coordinated system of assistance.

1.4 SCOPE AND STRUCTURE OF LITERATURE REVIEW

A search of the peer reviewed published literature was conducted along with a search of the grey literature of more informal materials. For the peer reviewed literature, the Web of Science bibliography was searched. The Web of Science is a service provided by Thomson Reuters and Clarivate Analytics. The service curates and compiles databases on citations for several academic disciplines. The aggregate citation and publication data can then be used in performing comprehensive literature searches and analyzing the search outcomes.

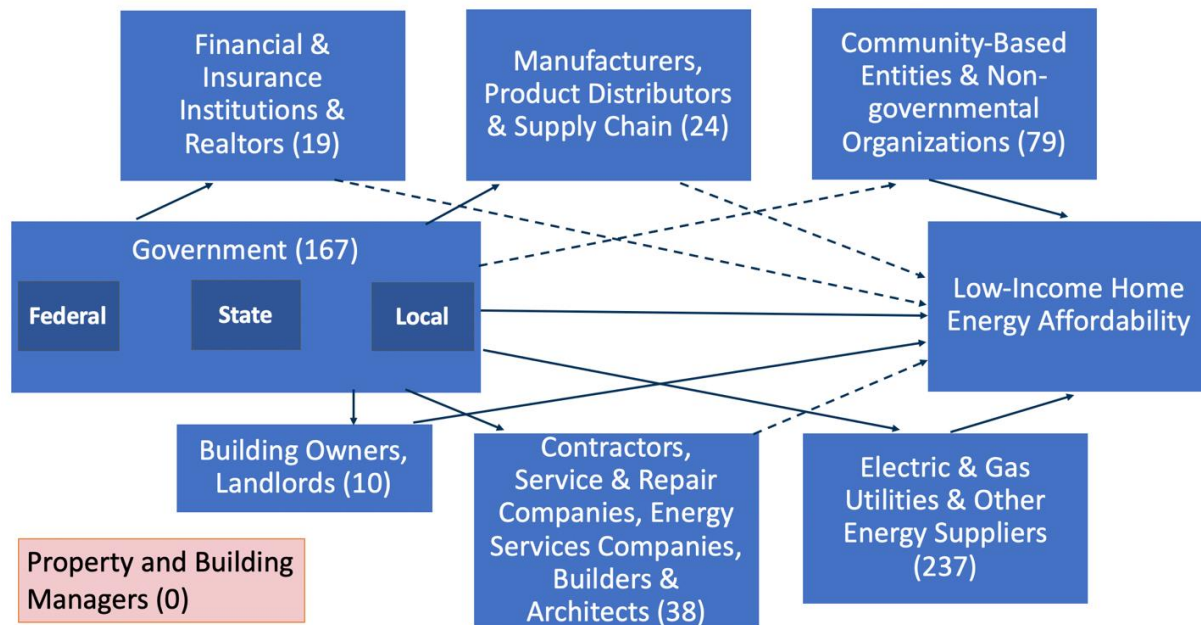


Figure 1.1. The array of stakeholders in the fragmented low-income housing market.
(Source: Authors)

Note: Numbers in parentheses are the frequency that stakeholders are mentioned in the abstracts of 183 publications examined for this review. Solid and dashed lines represent strong and weak connections, respectively.

A search protocol was established using a syntax of keywords that included synonyms of three attributes: (1) poverty and low-income households, (2) energy efficiency and solar energy, and (3) evaluation and data analysis. All three dimensions were required. In addition, at least one author had to be from the U.S., and the papers had to be published in the 2010-2019 timeframe. The resulting 270 peer-reviewed publications were “culled” for out-of-scope citations and also “mined” for additional references as the citations embedded in the original 270 publications were examined. This process produced a curated set of 171 publications. Several seminal references published earlier than 2010 are also cited in this report.

A Delphi approach to ensure consideration of the associated grey literature – including conference proceedings, trade association documents, and workshop presentations. In some instances, for instance, technology, program implementation, and policy innovations are so recent that the published literature has not yet addressed them.

The technology scope of this review is broad. Energy efficiency is a core technology of interest, referring to technologies, materials, and practices that require less energy to deliver a given service, such as heat, light, and warm water (Brown and Wang, 2015). Solar photovoltaic systems are also included in the technology scope, as well as electric vehicles, home storage, and microgrids because they too, can help to reduce energy burdens.

To manage and archive this vast information resource, an annotated bibliography of the literature reviewed in this paper is also available (Lapsa, Brown, and Soni, 2020).

While the scope is national, the review also highlights how geography, race, ethnicity, culture, health, and age create unique circumstances. Cities, suburbs, rural areas, island territories, and Indian reservations all offer different challenges and solutions. Low-income families with children and the elderly and disabled have different needs for energy and face different challenges to reduce their utility bills. Nevertheless, principles associated with successful programs and policies do emerge. In each section, we also summarize the key findings based on the dominant view in the literature that we examine. These findings are then summarized and organized into conclusions in Section 6, based on common themes and the preponderance of evidence from the literature review.

2. ENERGY BURDEN OF LOW-INCOME HOUSEHOLDS

Low-income households in the U.S. are diverse, as are their patterns of energy consumption. In this section, we describe alternative measures of energy burden, the energy consumption patterns of low-income households, how these patterns have changed over the past decade, and the causes and effects of high energy burden among low-income households.

2.1 MEASURING THE EXTENT OF THE BURDEN

To understand low-income energy burdens, it is important to examine the metrics used by analysts to characterize the energy consumption patterns of low-income households.

2.1.1 Variable and Inconsistent Definitions

Finding: Variable and inconsistent definitions and metrics are used to describe the energy consumption patterns of low-income households. The extent and nature of energy burden, and the estimated impact and value of solutions, depend upon the metrics used.

The term “household energy burden” has become a dominant construct used by analysts working on low-income energy issues in the U.S. Early and subsequent research conducted for DOE by Oak Ridge National Laboratory (ORNL) (Eisenberg, 2014) and Economic Opportunity Studies, Inc (Power, 2008) used energy burden as a means to characterize the U.S. population in need and to inform program and policy. The term is generally defined as the share of a household’s income that is spent on energy utilities (Drehobl and Ross, 2016). There are two parts to this definition – the numerator provides a measure of energy expenditure by the households, reflecting energy consumption and rates; the denominator is a measure of household income or budget.

Household energy expenditure is usually measured by looking at the total spending on household utility bills for heating, cooling, and other home energy services (Berry, Hronis, and Woodward, 2018). Most energy burden studies do not analyze household spending on transportation energy.

Household income or budget is also measured in a variety of ways, using different benchmarks. These include, the Federal Poverty Level (FPL), State Median Income (SMI), Area Median Income (AMI), and household budgets. The Supplemental Poverty Measure (SPM)³ conducted by the Census Bureau measures household income after including different sources of financial support. Accounting for households that receive different support payments and reducing them from the household income levels increases the level of poverty across most categories. The income benchmarks used to qualify households for different energy assistance programs can influence the program’s energy savings (Hoffman, 2017).

In fiscal year (FY) 2014 (October 1, 2013-September 30, 2014), the average annual weather-normalized expenditure for low-income households (at or below 200% of the federal poverty level) was estimated to be \$1,851 (Eisenberg, 2014, p. 10). About 39% of this (\$721) was estimated to be for primary heating and cooling expenses. Based on the same source, non-low-income households spent \$2,284 on residential energy in FY 2014, with \$906 (40%) spent for primary heating and cooling. Based on the 2009 Residential Energy Consumption Survey

³ <https://www.census.gov/prod/2012pubs/p60-244.pdf>

(RECS) and inflation adjustments, the average income of low-income households in FY 2014, was estimated to be \$18,773 compared to \$71,755 for non-low-income households. The resulting household energy burdens were estimated to be 16.3% for low-income households compared to 3.5% for non-low-income households (Eisenberg, 2014, p. 10).

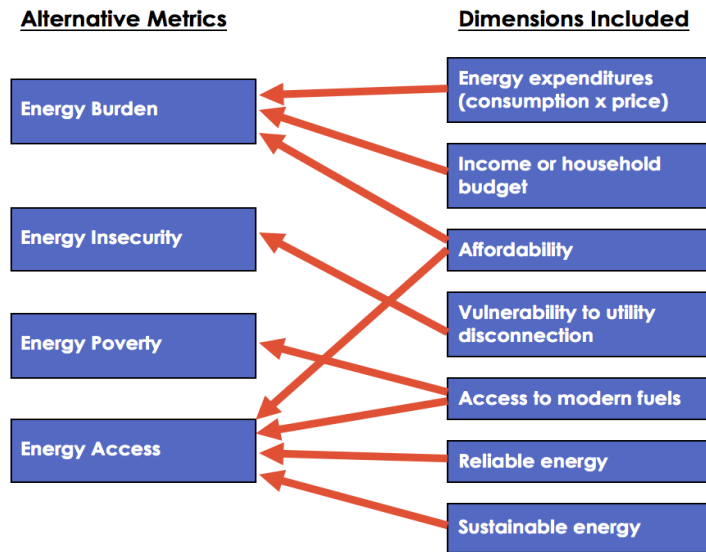


Figure 2.1. Scope of energy burden and related definitions.
(Source: Authors)

Based on household energy burden, Colton (2011) defines “energy poor households” as those spending more than 6% of their income on meeting energy costs. The premise for this benchmark is that a household should not spend more than 30% of its income on housing expenses, and the utility costs should not exceed 20% of these expenses. This threshold is often used for comparison purposes and to estimate the “affordability gap” (Fisher, Sheehan, and Colton, 2013). A range of thresholds has also been developed. In a study for the State of Colorado, Cook and Shah (2018a) distinguished between “energy stressed” households with energy burdens of 4-7%, “energy burdened” households with 7-10% energy burdens, and “energy impoverished” households with energy burdens greater than 10%.

A second construct – “energy insecurity” – refers to the uncertainty that a household might face in being able to make utility bill payments (Berry et al., 2018), which can ultimately result in being disconnected from energy services either permanently or temporarily (Verclas and Hsieh, 2018). Elnakat, Gomez, and Booth (2016) and Ross, Jarrett, and York (2016) document that the incidence of energy security varies by region with the highest rates in the South.

In contrast, the term “energy poverty” generally refers to living in a home that does not have access to enough energy to meet their essential needs. More functionally, it is described by the U.N. Development Program (UNDP, 2005) as the “inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read or for other household and productive activities at sunset.” Modern energy services are crucial to human well-being. About half a million Americans live without access to basic electricity services, and a majority of these households reside in U.S. territories or on American Indian reservations (Begay, 2018b; EIA, 2000).

In the international literature, “energy access” is a common term, and is recognized in the Sustainable Development Goals adopted by the United Nations in 2015. Further, the first target of the Sustainable Cities and Communities Goal (SDG 11) is access to adequate and affordable housing with basic services, which includes affordable utilities. SDG 7 aims to ensure access to affordable, reliable, sustainable and modern energy to all by 2030. Affordability and reliability are both critical components of energy burden analysis in the U.S. context, where high levels of access to energy exist as compared to other countries, but many groups face high energy burdens. SDGs were adopted in 2015 at the U.N. Sustainable Development Summit in New York. The SDGs are a continuation of the global pursuit of sustainable development which was first recognized in the 1992 Earth Summit in Rio de Janeiro through the Adoption of Agenda 21.⁴

In sum, multiple definitions are used to discuss low-income energy burdens, to qualify households for assistance in different programs, and to estimate the potential for future energy bill reductions (Hoffman, 2017). This is problematic because the extent and nature of the energy burden problem depends on the definition used (Figure 2.1).

- The problem of energy burden and vulnerability is more widespread when measured by a combination of indicators (Lin, 2018b), such as income poverty combined with hardship making bill payments (Berry et al., 2018).
- GIS mapping documents that using different definitions can lead to higher or lower estimates of energy burden in different types of regions; while income and energy poverty are highly correlated, the problem of high energy burden among the income poor is more pronounced for those living in rural areas (Lin, 2018b).
- Using a range of definitions of income and spatial densities to provide estimates of potential savings, Hoffman (2017) demonstrates that total savings and their distribution can vary greatly based on the definition of low-income households and communities.

2.1.2 Magnitudes, Distributions, and Trends

Finding: Energy burden is higher among low-income households than other income groups. The average energy burden of low-income households is not declining, and it continues to be high in particular geographies and socio-economic groups. Low-income households spend a higher proportion of their income on energy bills than any other income group (Eisenberg, 2014; Berry et al., 2018), spending on average three times more of their income on energy bills than higher income households (Drehobl and Ross, 2016). This is true, even though low-income households consume less energy per capita than other households. Evidence indicates that participants in the Weatherization Assistance Program (WAP) managed by the U.S. Department of Energy (DOE) have even higher energy burdens (Eisenberg, 2014). These high burdens were strong motivators to apply for services: 43% of respondents in one study reported this as a motivating factor (Rose et al., 2015, p. 22). This is consistent with the finding by Tonn, Rose, and Hawkins (2015, p. 5) that prior to weatherization, 65% of survey respondents reported that it was hard or very hard to pay for energy bills, while post-weatherization, the percentage dropped to 49%.

⁴ <https://sustainabledevelopment.un.org/outcomedocuments/agenda21>

High energy burdens produce energy insecurity. Residential Energy Consumption Survey (RECS) data for 2015 indicate that 31% of all U.S. households experienced some form of energy insecurity – often foregoing food and medicine in order to pay an energy bill. These rates were particularly high in mobile homes (58%) and in apartments in buildings with 2-4 units (46%) (Berry et al., 2018). In 2015, nearly seven million households had their access to heat interrupted at least once, and six million lost access to air conditioning at least once (Verclas and Hsieh, 2018).

Energy security is significantly more problematic for low-income households. Based on a national survey in 2015, 40% of households with income below \$50,000 find it difficult to pay their energy bills at least “once in a while”.⁵ In 2017, one-third of consumers with household incomes of less than \$50,000 had trouble paying their electric or heating bills at least sometimes, 7% more than in 2016, despite the stronger economy (Treadway, 2018). Utility disconnections are difficult to track because most states do not require utilities to record these numbers. However, there is an exception in some states where utilities file these numbers with the Public Utility Commissions (Verclas and Hsieh, 2018). The number of disconnections appears to be increasing in at least two states. In Texas, the number of recorded disconnections increased by 64% between 2010 and 2016, and in California, the numbers tripled between 2006 and 2016 (Verclas and Hsieh, 2018). The authors further note that low-income households (with incomes less than \$20,000) were almost three times as likely to face energy insecurity as households with income greater than \$60,000. A simple but nonetheless meaningful definition of energy access is the ability to get utility service, which is impacted by the disconnection practices and policies of utilities.

Just as energy security is not improving, the average energy burden of low-income households is also not declining. To assess trends and geographic variations in energy burden, Fisher, Sheehan and Colton define the home energy affordability gap as the difference between actual home energy bills and affordable home energy bills.⁶ The actual bills are calculated as a function of energy usage, housing, and weather characteristics. As noted earlier, the affordable burden is set at 6% of the household’s income. The gap is calculated at a county-by-county and state-by-state level, for different segments of the low-income populations starting at 50% and going up to 200% of the household federal poverty level. Based on updated national estimates, the home energy affordability gap index for the U.S. in 2018 was 134.4 (compared to the indexed value of 100 in 2011).^{7 8} In monetary terms, this is equivalent to \$51.8 billion. The report also provides a summary of this distribution across census regions. The Mountain region had the highest Home Energy Affordability Gap Index at 284.6. This translates to \$3.7 billion in 2018, compared to \$1.3 billion in the base year, 2011.

At the same time that these indicators show that neither energy affordability nor energy security are improving, program evaluations document clearly that the energy affordability for the millions of homes that have received weatherization and energy-efficiency services has, in aggregate, improved (see Section 4). The average burden of low-income households overall has

⁵ <http://defgllc.com/news/article/how-well-are-you-reading-your-low-income-customers/#/>

⁶ http://www.homeenergyaffordabilitygap.com/01_whatIsHEAG2.html

⁷ http://www.homeenergyaffordabilitygap.com/03a_affordabilityData.html

⁸

http://www.homeenergyaffordabilitygap.com/downloads/2018_Released_Apr19/HEAG2018%20Regional%20Fact%20Sheets.pdf

not declined largely because only a fraction of the total eligible population has received such services.

The energy consumption patterns of low-income households vary with gender, age, race, education, health and disability status, as well as cultural attributes and occupations of members (Tonn et al. 2015, 2015b). Elnakat et al. (2016) found that households in zip code areas where the median age of the household head was less than 30 years, used significantly less energy per capita than zip code areas with median ages above 40 years. Zip codes with a higher percentage of high school graduates also had higher levels of energy consumption.

Geography is also important: household energy patterns vary widely across highly urbanized areas (Porse et al., 2016), suburbs (Verclas, 2018), rural and remote locations (Souba and Mendelson, 2018; Lin, 2018b; Ross, Drehobl, and Stickles, 2018; Begay, 2018a, b) and climate regions (Ross, Jarrett & York, 2016). Many low-income households have experienced generations of the poverty cycle, especially the chronically unemployed including disabled individuals who are dependent on public assistance or charitable support for survival. Others have recently experienced income declines, due to shifting job opportunities and retirement from the workforce. Some have chosen a low-paying profession such as artists, writers, and community activists. Still others are unskilled or semi-skilled, working in low-wage jobs in retail, hospitality, and health services. Energy decision making varies across all of these groups (Schwartz, 2014).

The problems of high energy burden and insecurity are more severe in minority households and those with children and older residents (Berry et al., 2018). Hernandez, Aratani, and Jiang (2014) found that black households with children were more likely than any other group to experience energy insecurity, after controlling for income. Kontokosta, Reina, and Bonczak (2019) examined an extensive database describing 3,122 census block groups (CBGs) in five U.S. cities. Of these CBGs, 42% were classified as predominantly minority neighborhoods, and the remainder were predominantly non-hispanic white neighborhoods. For the three lowest income groups ($\leq 50\%$, 51%–80%, and 81%–120% AMI), energy burdens in the two types of neighborhoods were statistically distinct. Very-low-income residents ($\leq 50\%$ AMI) in minority neighborhoods had energy burdens that were 1.56% higher than households of the same income category living in predominantly non-hispanic white communities. A similar difference was identified in the two other low-income groups (51%–80% AMI and 81%–120% AMI), although the gap in energy burden was smaller (Kontokosta, Reina, and Bonczak, 2019).

Energy burden also tends to be concentrated in rural areas, and states in the East South Central, New England and Mid-Atlantic regions have the highest rural energy burdens (Ross, Drehobl, and Stickles, 2018). Hoffman (2017) cautions against using aggregate national or regional indicators of energy burden, arguing that they can significantly underestimate the number of eligible households because the extremes in the distribution disappear when averages are examined.

2.2 CAUSES OF HIGH ENERGY BURDEN

The underlying causes of high energy burden identified in literature can be divided into five main categories – location and geography, housing characteristics, socio-economic situation, energy prices and policies, and behavioral factors (Table 2.1).

The first category of causes and correlates is geographic location, which is a strong predictor of energy burden. Low-income residents of rural communities and island territories pay higher-than-average bills for both electricity and heating fuels (Shoemaker, Gilleo, and Ferguson, 2018). With high energy costs, the benefits of energy efficiency could be significant, but rural residents face numerous other barriers such as a generally older housing stock that has produced a “rural energy-efficiency gap” (Winner et al., 2018).

Similarly, low-income households in the nation’s largest cities face higher-than-average energy burdens (Drehobl and Ross, 2016). Fox (2016) and Brown⁹ document the problem of low-income burdens in Southeastern states,¹⁰ where poverty rates are high, and households consume significant amounts of energy for both heating and cooling to keep their aging and poorly built homes livable. There is a correlation between the types of fuels used for heating and cooling and their impacts on the household bills. HVAC systems in the South tend to be electric whereas heating in most other regions is dominated by natural gas, which is more affordable. In summer months and in hotter climates, households with electric space conditioning have greater opportunities to save energy (Bradshaw, Bou-Zeid, and Harris, 2016) whereas in the winter months, there is more potential to save energy in the colder regions (Bradshaw et al., 2014; 2016).

Finally, low-income neighborhoods can lack access to efficient appliances. For example, Reams, Reiner, and Stacey (2018) found that energy-efficient bulbs are less available in low-income areas, based on in-store surveys conducted in Wayne County, Michigan.

Second, housing characteristics are a major determinant of energy consumption and intensity (consumption per square foot). Older homes, public housing, and multifamily units also correlate with high energy intensity (Berkland, Pande, and Moezzi, 2018; Langevin, Gurian and Wen, 2013). Variation in maintenance and housing quality also manifests in the form of different levels of gas and electricity consumption (Scheu et al., 2018). Typically, low-income houses are older and undergo fewer repairs and upgrades over time. As a result, these housing units usually have inefficient insulation and older appliances, further adding to the energy burden (Cabeza et al., 2014). Bradshaw et al. (2014) also conclude that the overall savings potentials ultimately depend on the housing stock and the space conditioning equipment in use. In sum, much of the affordable housing/low-income housing in the U.S. remains energy inefficient despite advancements in building technologies and science.

Third, socio-economic characteristics determine a household’s ability to afford energy-efficiency retrofits and more energy-efficient appliances (Thorve et al., 2018). Based on 2015 data from the Residential Energy Consumption Survey, low-income households use less energy than any other income group. However, they have the highest energy burdens, particularly households with incomes less than \$20,000, whose energy burdens are more than twice as high as households who earn \$20,000-\$40,000.¹¹ While high-income households consume more energy, their EUI (that is, energy use per square foot of housing) is lower (Bednar et al., 2017).

⁹ https://cepl.gatech.edu/sites/default/files/attachments/SCEN_PPT_Energy_Equity_05-30-18-Final_0.pdf

¹⁰ https://www.energy.gov/sites/prod/files/2019/01/f58/WIP-Energy-Burden_final.pdf

¹¹ https://www.nclc.org/images/pdf/special_projects/climate_change/report-reversing-energy-system-inequity.pdf

Table 2.1. Causes and Correlates of High Energy Burden

Location and Geography	Housing Characteristics	Socio-economic Situation	Energy Prices and Policies	Behavioral Factors
• Rural, urban, Native American, remote community, island territory • Climate • Population density • Urban morphology (affecting access to jobs and efficient appliances)	• Thermal integrity of building • Type, age and size: single-family, manufactured, multifamily) • Owner-occupied vs rental and public housing • Age and type of appliances • Type of thermostat: WiFi, smart, programmable, touch screen	• Income • Ethnicity/Racial background • Immigrant vs native-born • Number of occupants, children, elderly, and handicapped	• Energy prices • Energy rate designs • Energy mix and access to natural gas • Availability and effectiveness of low-income energy programs and appliances	• Lack of knowledge • Misplaced incentives/principal-agent problems (especially in multifamily homes) • Lifestyle cultural factors • Lack of control over energy bills • High non-monetary costs

Race and ethnicity also correlate with overall energy use, level of energy burden, and household energy consumption patterns. Hernandez et al (2016) and Bednar et al. (2017) find that African Americans have higher utility costs and higher Energy Use Intensity (EUI), as do Hispanic households. The underlying causes of these patterns are complex, but likely include impacts from historical housing injustices such as Jim Crow laws that enforced racial segregation. In addition, the size and composition of a household are key determinants of household energy consumption. Some of the same patterns are emerging in studies of other advanced energy technologies. For instance, Sunter et al. (2019) analyze rooftop solar adoption across the country and find that census tracts with larger shares of racial and ethnic minority groups have lower rates of adoption compared to white-majority census tracts.

Understanding the relationship between social demographics, load shapes and energy burden is only now emerging as a research focus (Jaske, 2016), which is particularly promising because it could help to guide efforts to manage consumption during the hours when it matters most.

The fourth category of causes and correlates of high energy burden is prices and policies. For example, high fixed components in power bills or reconnection fees are important barriers to reducing energy bills. These are discussed further in Section 3.

The fifth category covers behavioral determinants of energy consumption. Lack of knowledge and split incentives can be major hurdles to well-functioning housing markets, undermining investments in home retrofits and participation in energy efficiency programs. Building owners and managers know more about the energy performance and efficiency of their buildings than do prospective buyers and tenants, leading to the well documented situation of “lemons”, when consumers buy energy-inefficient appliances and homes because of imperfect marketplace

information (Brown and Wang, 2015). Split incentives are especially evident in rental apartments where tenants do not have control over appliance choices and energy conservation measures, but they have to pay the bills (Brown, 2001). Tenants are often beholden to building owners and managers to make smart energy decisions based on their understanding of the energy integrity of the units. Tenants that are not provided information on behavior solutions or provided technical improvements, are likely to remain in situations of high energy use and burden (Berkland et al, 2018). In addition, residents of rental housing do not always have control over their energy bills; for example, building management may control the heating and cooling settings, resulting in thermal discomfort. This asymmetry of information and lack of control renders tenants vulnerable to high bills and the possibility of eviction.

Despite the stated willingness of most households to conserve energy and invest in energy-efficient appliances, there is often inconsistency between these values and their actual purchase behavior. These inconsistencies are sometimes based on various personal and contextual constraints including lack of available capital and nearby vendors (Brown and Sovacool, 2018).

Some energy programs have long waitlists of eligible program participants, while others face difficulty meeting their outreach and participation goals (Hirshfield and Iyer, 2012). From the utility's perspective, the small scale and dispersed nature of energy-efficiency projects challenges the aggregation of this resource, increasing its transaction costs. Effort is required to fill the "pipeline" with energy-efficiency projects that are investment-ready and creditworthy (Brown and Wang, 2015).

Such transaction costs suggest the case for utility partnerships with local community agencies that offer human services and already have people with completed income qualification paperwork for other programs (food, housing, medical care, etc.). This is particularly valuable for a program like WAP because its administrative costs are generally capped at 10%. (10 CFR 440). To take advantage of shared resources, WAP tends to be delivered alongside other social service programs so that transaction costs can be shared under the larger umbrella program (Community Action Agency). These types of transaction cost savings also motivated the MOU between DOE and HUD, which provided lists of income eligible "properties".

2.3 EFFECTS OF HIGH ENERGY BURDEN

High energy burdens have far-reaching and enduring consequences. Broadly defined, high energy burdens for low-income households have two types of inter-locking effects related to household economics and health.

Adverse economic and financial consequences often occur when low-income households with high utility bills have to make trade-offs between meeting alternative critical household expenditures. Paying for food, medical care, telecommunications, and shelter are often sacrificed in order to make timely utility bill payments (Hernandez et al., 2016; Camprubi et al., 2016). These trade-offs create a negative feedback loop that traps families in an enduring cycle of poverty. For example:

- Low-income families unable to pay their high energy bills become vulnerable to utility shut offs, which can lead to homelessness.

- Cash-strapped families and individuals become prey to predatory payday loans as their only option to pay utility bills and avoid shutoffs, which come with high interest rates that make repayment difficult¹² (Tonn et al., 2015).

Adverse health effects of high energy burdens can span a range of illnesses and conditions. These include exposure to carbon monoxide poisoning and other indoor air pollution due to the inefficient and improper use of unvented and subserviced wood stoves and propane heaters¹³ (Fabian, Adamkiewicz, and Levy, 2012).¹⁴ Other health effects noted in the literature are mental stress, lead exposure, thermal discomfort and respiratory problems such as asthma (Fabian et al., 2014; Wells et al., 2015; Chen, Xu, and Day, 2017). The fear of not being able to pay bills and the potential of losing electricity and home gas heating utility service altogether can stress mental health problems. There are also health effects related to inefficient energy usage and poorly insulated buildings. These effects are amplified for groups vulnerable to these conditions that often have limited adaptive capacity because of fewer resources (Hernandez et al., 2016; Massetti et al., 2017).

¹² https://cepl.gatech.edu/sites/default/files/attachments/SCEN_PPT_Energy_Equity_05-30-18-Final_0.pdf

¹³ <https://ktvl.com/news/local/wood-stove-and-heater-source-of-two-deaths-in-sisikyou-county>

¹⁴ Propane should be burned in an ideal ratio of 4 parts propane to 96 parts oxygen. Otherwise, it can lead to incomplete combustion of the fuel, which in turn releases carbon monoxide, a hazardous substance, especially when used in poorly ventilated areas. See: <https://heattalk.com/propane-heat-pros-and-cons/>

3. THE ECOSYSTEM OF LOW-INCOME ENERGY PROGRAMS AND POLICIES

Across the U.S., many programs and policies could help to address the energy burdens of low-income households.

3.1 TYPES OF PROGRAMS AND LEVELS OF EXPENDITURE

Finding: Many policies and programs that promote energy efficiency and renewable energy (e.g., rebates for Energy Star appliances and utility incentives for rooftop solar) are largely inaccessible to low-income households due to affordability barriers, although several states and coalitions of NGOs have recently launched major low-income solar programs and Energy Efficiency for All initiatives. Funding for temporary assistance (e.g., for bill payments) dwarfs funding for more enduring assistance (e.g., weatherization) (Hoffman et al., 2018; Cluett, Amann, and Ou, 2016), though both serve a critical need and benefit from being linked together. Funding for low-income energy programs peaked as a result of the American Recovery and Reinvestment Act (ARRA); it has returned to levels above the pre-ARRA funding, reflecting modest increases in weatherization funding and more substantial increases in low-income solar programs (O'Dwyer, 2017).

Since the mid-1970s, numerous programs and policies have been implemented in the U.S. to promote residential energy efficiency and reduce household energy bills (Berg et al., 2018; Brown and Wang, 2015). For example, state building codes have improved the energy integrity of new home construction, and appliance standards have raised the energy performance of household equipment, arguably becoming the largest contributor to the energy efficiency of low-income housing today. In addition, financial incentives in the form of income tax credits and tax-free loans are available for taxpaying households to make investments in energy efficiency and renewable energy projects. However, participation from low-income households remains low (Zhao et al., 2012). In contrast, weak energy-efficiency regulations can also disadvantage low-income households. For example, while few low-income households live in new homes, the fact that poor building codes cause homes to be built without a focus on energy creates a missed opportunity with an impact that can last a century and ultimately challenge the affordability of low-income households. Energy Star ratings have helped educate consumers about the energy consequences of the products they purchase, and federal tax policies have subsidized home energy retrofits. Several states also offer low-income homeowners financial incentives to overcome the high up-front cost of energy-efficiency appliances and equipment.¹⁵ However, participating in these programs (purchasing new appliances and retrofitting homes) is not affordable for many low-income households.

More recently, policies and programs have been launched to accelerate the deployment of energy efficiency and renewable energy. These include more than a decade of federal investment tax incentives and utility net metering programs that support rooftop solar panels and home battery storage systems. The federal government provides tax rebates to subsidize the purchase of electric vehicles, and many states are implementing programs to pay for the development of vehicle charging infrastructure (Narassimhan and Johnson, 2018). We do not review this

¹⁵ Database of State Incentives for Renewables & Efficiency (DSIRE) Financial Incentives for Energy Efficiency (2012). <https://programs.dsireusa.org/system/program/tables>

complex ecosystem of policies because low-income households generally cannot afford to purchase new electric vehicles even with the rebates that are offered.

However, questions are being asked about the fairness of incentives that promote a transition to energy efficiency and renewable energy technologies when they are largely inaccessible to low-income households. For example, Cluett et al. (2016) note that a majority of utility energy-efficiency programs require an up-front customer investment to leverage rebates and associated savings, which makes them unaffordable to low-income households. Low-income households often cannot afford the up-front financial “match” required to obtain the rebates and loans available to consumers who buy energy-efficient household appliances. As a final example, the federal government promotes residential energy-efficiency and solar systems investments by offering tax credits. In the case of rooftop solar systems, these are called Investment Tax Credits. Such federal tax credits are worth very little to most low-income homeowners because they typically have limited tax liability.

This inequity is compounded by the fact that energy-efficiency programs raise electric and other utility costs by increasing the share of fixed utility fees for all customers (Johnson et al., 2017; Sigrin and Mooney, 2018). While such inequitable impacts of electricity and natural gas tariffs can be offset by modest low-income energy assistance programs (Borenstein and Davis, 2012), such offsets are rarely established.

Within the U.S. policy ecosystem, numerous and diverse energy programs and policies do target low-income households. Table 3.1 summarizes these in a matrix organized by implementing organization and type of program. Program implementers range from electric and gas utilities and federal and state agencies, to local government and community-based entities and philanthropic and nonprofit organizations. Program types distinguish between utility bill assistance, financial incentives, energy information, and regulations. Initiatives (such as the Clean Energy for Low Income Communities Accelerator or CELICA) have also facilitated cross-organizational coordination in this space. The CELICA program helped lower energy bills for households by facilitating a partnership between the DOE and sub-national governments (DOE, 2017). Gilleo, Nowak, and Drehobl (2017) identify some core practices of successful low-income energy efficiency programs. Some of these include ensuring statewide coordination, targeting program offerings to sections that yield the highest benefits, forming partnerships with local outreach organizations, and providing a single point of contact to participants and contractors.

Table 3.1 Illustrative low-income energy policies and programs

	Energy Bill Assistance	Financial Incentives	Energy Information	Regulations
Electric and Gas Utilities	• Bill forgiveness programs • Budget billing • Prepaid electricity services • Payment plans	• Direct installation of efficiency measures • Round-up assistance programs • On-bill program designs	• Goal setting for low-income programs • Installation of home energy management systems • Real-time appliance and premise level feedback	• Rates and rate design • Shut-off and reconnection policies • Integrated resource planning • Adders for cost-effectiveness tests • Minimum requirements for low-income programs
Federal Agencies	• Low Income Home Energy Assistance Program (LIHEAP) • HUD assisted housing utility allowance subsidies • USDA housing utility allowance subsidies	• Weatherization Assistance Program (WAP) • LIHEAP weatherization • Energy Efficiency and Conservation Loan Program (EECLP) • Low-Income Housing Tax Credit (LIHTC) program • HUD HOME/CDBG home repair funding	• WAP includes education of clients as an allowable activity • WAP Technical Assistance and Training • HUD Utility Benchmarking guidance	• Subsidized housing regulations • Federal Housing Administration (FHA) Duty to Serve • Environmental Protection Agency (EPA) energy justice and climate regulations • Federal Energy Regulatory Commission (FERC) affordable power for all regulations
State Agencies	• Implementation of federal bill assistance programs • State administered ratepayer funding for bill assistance	• Implementation of federal low-income energy efficiency programs including support for local, state and regional initiatives • State and county funds supplement WAP	• Technical assistance • Tools • Case studies • Peer exchange • Goal setting • Convening • Stakeholder engagement	• Subsidized housing regulations • Minimum requirements for low-income utility programs
Local Government, Community-Based Entities, and NGOs	• Bill forgiveness programs	• Weatherize Campaigns • Home repair financing	• Healthy housing programs • CDC Lead Control • Building codes and ordinances • Community education, outreach • Community convening • Pilot projects	• Subsidized housing regulations • Building and energy codes and standards

Based on data principally from 2013 (see the notes for Figure 3.1), approximately 80% (or about \$6.3 billion) of low-income energy funding goes to bill payment assistance, 14% (\$1.17 billion) to energy efficiency, and 5% (\$38 million) to unspecified support (Cluett et al., 2016, p. 7). Altogether, utilities are the single largest source of funding for low-income energy programs. Ratepayer-funded utility programs provide 41% of the total funding for low-income bill assistance and 10% of the total funding for low-income energy-efficiency programs. Thus, Public Service Commissions, Boards of Directors of public utilities, and other state regulators

are critical to establishing the policy ecosystem within which utilities design and implement low-income energy programs. Federal agencies provide 44% of the total (40% from LIHEAP for bill assistance, 2% from LIHEAP for efficiency, and 2% from DOE for the Weatherization Assistance Program). In 2016, the block grant allocation to LIHEAP was \$3.3 billion, reallocation funds were \$1.2 million, and funds carried over from previous year was \$167 million.¹⁶ State and local contributions at 3% and nonprofit organizations at 2% complete the picture. These funds are used for heating and cooling assistance, crisis assistance, administrative and planning needs and any other requirements at the state level. These sources are somewhat dated and cross-cut different years, as would be expected from a review of the literature, which is distinct from a review of information in databases.¹⁷

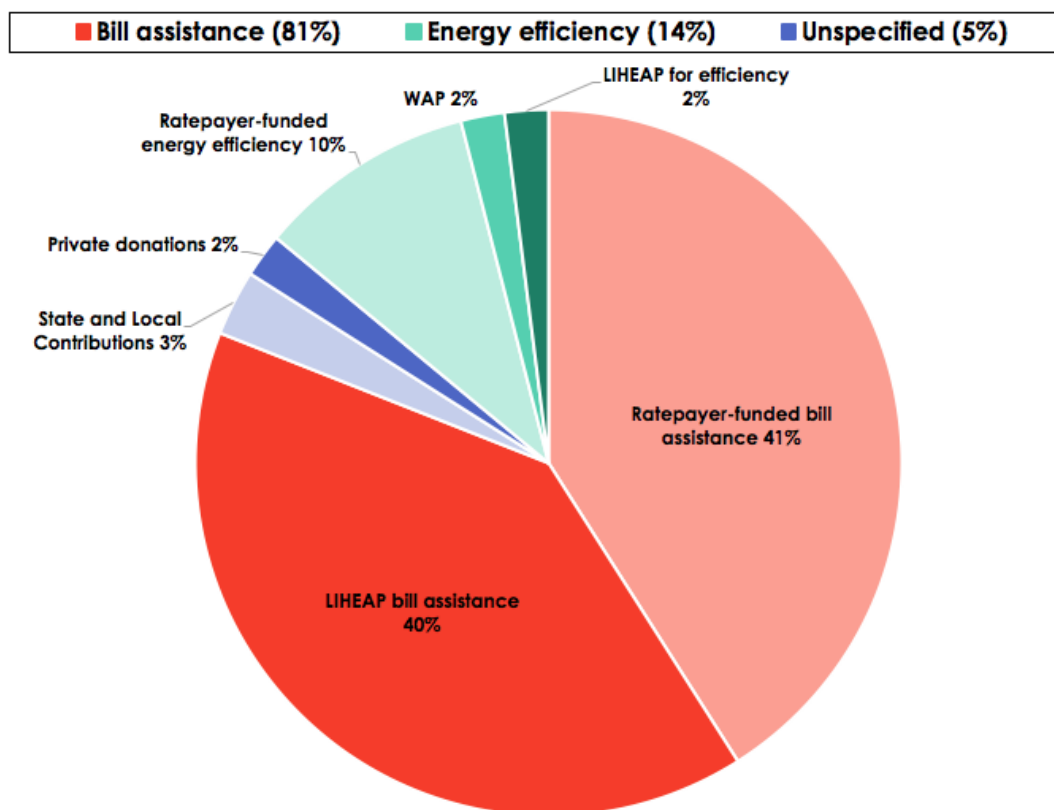


Figure 3.1 Expenditures on low-income energy programs
(Redrawn from Cluett et al., 2016, Figure 2)

(Notes: Funding for most of the categories are based on data for 2013; LIHEAP spending on efficiency is based on 6% of LIHEAP funds spent on efficiency in 2006. Data on state and local contributions and private donations are estimated for 2010, based on LIHEAP Clearinghouse 2016. Excludes solar programs and some affordable housing energy incentives, e.g., tax credit financing.)

¹⁶ <https://liheappm.acf.hhs.gov>

¹⁷ More updated sources for WAP and LIHEAP (including LIHEAP Wx funding) can be found at <https://nascsp.org/wap/weatherization-publications/wap-annual-funding-surveys/>

Over the past decade, annual expenditures on low-income energy-efficiency programs have ranged widely between about \$1-\$3 billion/year. The greatest source of variability is the funding for DOE's WAP. The American Recovery and Reinvestment Act (ARRA) of 2009 raised WAP's appropriations from historic levels of \$150 to \$230 million each year since its inception in the late 1970s, to \$5 billion between 2009 and 2011. As a result, WAP in 2010 spent an unprecedented \$2 billion, implemented by nearly 60 Grantees and about 1,000 Subgrantees. With leveraging, the national weatherization network expenditures rose to \$2.7 billion in program year 2010 (Tonn, et al., 2015, p. xvi).¹⁸ In the post-ARRA period, WAP has been operating at approximately the pre-ARRA Congressional appropriation level, peaking in 2019 at \$254 million.¹⁹

In addition to these funds, some states and counties use General Assistance, emergency assistance, local tax revenues, or similar funds to supplement federal LIHEAP funding. These funds may help low-income families pay for fuel, utilities, furnace repair, or other charges; some also help households avoid utility shut offs during summer/winter. Eligibility criteria vary by state; for example, some states require that applicants must be in an emergency condition.²⁰

Corporate and private funds also support fuel assistance for low-income households. Eligibility is variable, but typically requires an emergency situation. Program administrators are typically state social services agencies. One of the largest funds is managed by the Citizens Energy Corporation, which uses proceeds from natural gas sales to provide charitable emergency assistance to 25 states.²¹

3.2 ELECTRIC AND GAS UTILITY PROGRAMS AND POLICIES

Finding: The share of utility residential energy-efficiency funding that supports low-income households is lower than the percent of residential utility customers who are low-income (Drehobl and Castro-Alvarez, 2017).

Public utility commissions and city councils set customer benefit surcharges that are collected through customer utility bills. Utilities then use this money to fund low-income energy-efficiency programs. In 2014, energy efficiency spending for low-income programs accounted for 18% of residential electric efficiency spending and 34% of residential natural gas efficiency spending. The target segment of the population accounts for roughly one-third of total households, although this depends on how low-income status is defined.

Low-income households are not excluded from programs offered to all residential customers, but data show that they are less likely than other customers to participate in them.²² Non-low-income utility energy-efficiency programs, for example, often target homeowners and not renters, and they typically require participants to pay for a portion of the weatherization costs, which can be prohibitive for low-income households who tend to rent their homes and have limited

¹⁸ To spend the additional funding, income eligibility requirements were extended to 200% of the federal poverty level (rather than 150%), and the maximum WAP investment allowed per home was raised from \$2500 to \$6500. As a result, participating households had higher incomes and fewer vulnerable household members (Tonn, Rose, and Hawkins, 2015).

¹⁹ <https://nascsp.org/wp-content/uploads/2018/02/fy201720wip20fact20sheet.pdf>; <https://www.edf.org/energy/equity-through-energy-efficiency>

²⁰ <http://neada.org/state-tribal-programs/state-energy-assistance-directors/>

²¹ <https://www.ncoa.org/wp-content/uploads/Alternative-Sources-of-Energy-Assistance.pdf>

²² https://beccconference.org/wp-content/uploads/2015/10/presentation_frank.pdf

discretionary income. Because of their limited means, low-income households are also least able to participate in many types of initiatives aimed at reducing energy costs. At the state level, resources are typically insufficient to deliver energy efficiency and renewable energy services for all low-income households. A study of such policies in New York State concluded that markets are not always able to meet the public policy objectives (CEAC, 2017). The study recommends that to address the needs of the state, the utilities and the regulatory commission should follow a holistic approach such that the often-insufficient budgets are used towards cross-cutting initiatives to reach the largest portion of the state's population.

Relf, Baatz, and Nowak (2017) estimate that on average, utilities enabled (through financing and assistance) 5.29 kWh of low-income energy savings per residential customer and spent 8.93% of total energy-efficiency program funds (including residential, commercial, and industrial programs) on low-income programs in 2016. However, the low medians for both of these statistics (2.80 kWh/residential customer and 6.23% of total spending), indicate that the top performers are boosting the group average. For example, 22 utilities offer comprehensive programs including more than one low-income program as well as natural gas programs.

A similar pattern of spending and accomplishment was reported in a survey of the nation's 51 largest metropolitan statistical areas. In 2015, 49 metropolitan statistical areas (MSAs) were served by a low-income electricity efficiency program, and 31 were served by a low-income natural gas efficiency program. But the amount spent and savings achieved are highly variable across programs and fuels (See Table 3.2).

Table 3.2 Summary of Amount Spent and Savings Achieved Across Programs and Fuels, in 2015

(Source of data: Drehobl and Castro-Alvarez, 2017).

Electric energy efficiency programs		
Spending	Average spending on electric efficiency programs per low-income participant was \$1,538	Per low-income customer, these averages drop to \$3.
Savings	Producing 1,377 kWh of savings.	Producing 22 kWh of savings.
Natural gas programs		
Spending	Average spending on electric efficiency programs per low-income participant was \$2,002	Per low-income customer, these averages drop to \$23.
Savings	Producing 135 therms of savings	Producing 3 therms of savings.

The cities with the largest expenditures per low-income customer were Boston, San Antonio, Providence, San Francisco, and Hartford. In terms of kWh of electricity savings per low-income customer, the most impactful cities were Boston, Hartford, San Antonio, Providence, and Louisville, which each saved >50 kWh per low-income customer (Figure 3.2). About half of the

electric and natural gas programs coordinated with WAP in 2015, indicating significant potential for improved leveraging. Many, but not all programs target specific households such as high energy users, which also indicates room for improvement. State WAP grantees specify priority populations in their annual state plans, targeting elderly, disabled, families with children, and high energy users in accordance with the WAP statute. What this map does not show is how much is spent per customer. Some areas have a lot more to spend or may decide to spread resources more broadly on low-income households.

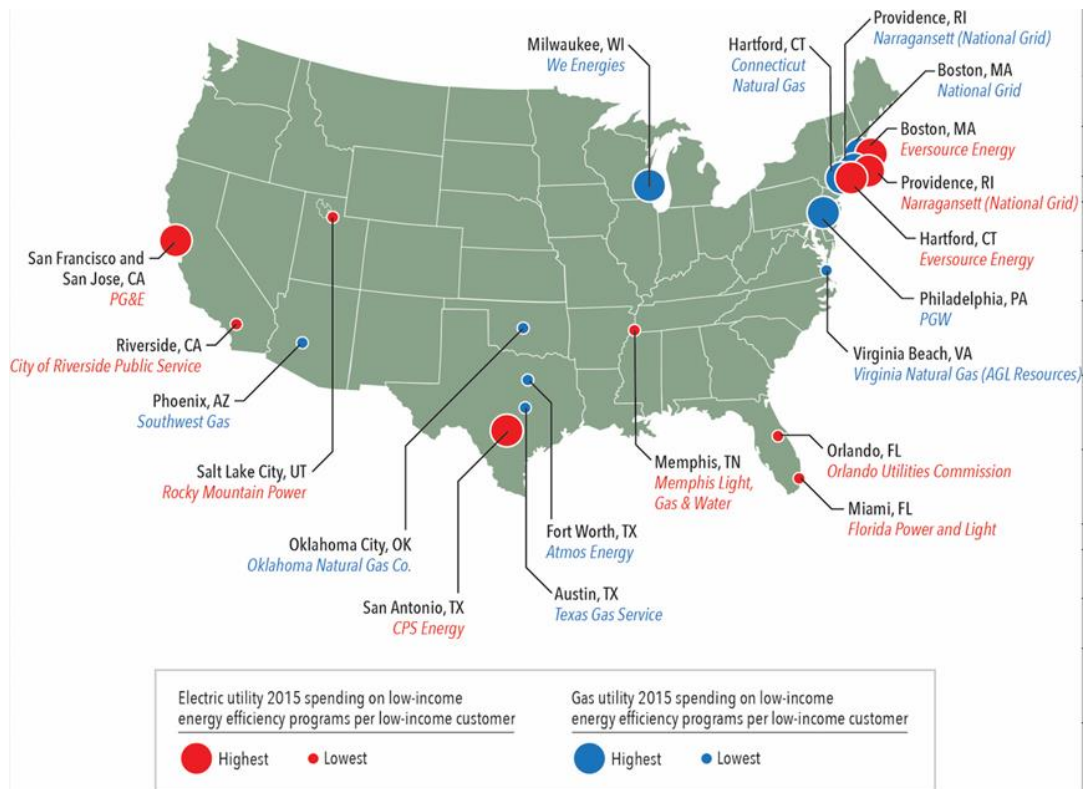


Figure 3.2. Electric and gas utility spending on low-income energy-efficiency programs per low-income customer in 2015.

(Source: Authors, based on data from Dreobl and Castro-Alvarez, 2017)

Across rural America, utility expenditures on energy-efficiency programs are lagging behind. Evidence from 12 utilities offering tariffed on-bill financing (Hummel and Lachman, 2018), and detailed analysis of on-bill programs implemented by a rural electric co-op in Arkansas suggests that the Pay-as-You-Save approach offers an effective approach. Household energy usage was decreased by almost a quarter, and the utility benefited from peak demand reduction, as well (Lin, 2018a). These results suggest a promising approach for the more than 900 cooperatives in the country. (See Section 3.2.2 below.)

Utility companies offer an array of programs and policies to help customers who are in arrears and to recover costs associated with non-payment. Utilities can implement prepaid electric service (see Section 3.2.4 below), offer payment plans (see Section 3.2.5 below), and implement alternatives to shutting off services. They can also eliminate late fees and interest and can promote level billing to reduce spikes in prices during extreme weather events. However, there is also evidence of the potential negative impact of some of these programs leading to “self-

disconnection”, propagating inequities, and adding stress to the households under difficult financial situations.²³

Utility companies and their customers can both benefit from such activities by reducing costs associated with shut-offs and reconnections (Hernandez and Bird, 2010). While these services and procedures are not intended to be long-term solutions to the low-income energy burden problem (Verclas and Hsieh, 2018), they can be effective in the short-run until the housing stock, HVAC equipment, and appliances can be made more energy efficient.

3.2.1 Integrated Resource Planning, Goal Setting, and Cost-Effectiveness Tests

Many utilities have a history of using ratepayer resources to support low-income energy programs. In regulated markets, these programs are often proposed in integrated resource plans (IRPs) that are typically written every three years or so by utilities and reviewed by Public Utility Commissions or other regulatory entities. Goals may be set by these Commissions, and cost-effectiveness tests are often deployed to determine if subsequent investments are cost-justified. Regulators of public utilities, such as the Board of Directors of the Tennessee Valley Authority (TVA) can authorize budgets for such expenditures. This was the case with the “Extreme Energy Makeover Program” low-income program launched in 2015, which was approved by the TVA Board as a response to EPA regulations and fines. The program targeted around 800 old homes (20 years+) located in lower-income communities and it had an electric energy usage reduction target of 25% per home.²⁴

Local power companies can also initiate program and project proposals, which are then reviewed by Utility Commissions and may be discussed in public hearings independent of IRPs. Typically, Utility Commissions specify in advance the cost-effectiveness tests that will be used to evaluate such proposals. Different tests dominate different regions of the U.S. For instance, the Rate Impact Measure (or “nonparticipant test”) is relied upon in the Southeast, while California and the Pacific Northwest emphasize the Total Resource Cost test and the Societal test that allows for the inclusion of the cost of environmental externalities. The more that societal impacts are considered (such as environmental and public health benefits), the higher the benefit-cost ratio of low-income energy-efficiency expenditures.

3.2.2 Residential On-Bill Program Designs

A residential on-bill program is a type of financing design that can be explicitly used to incentivize energy-efficiency projects by low-income utility customers. It is a financial product that is serviced by a utility company for energy-efficiency improvements in a building and is repaid by owners on their monthly utility bills. Such tariff designs can help overcome liquidity and budget constraints of low-income households. The utility pays the up-front cost of a project, and customers repay the utility as savings accrue each month. Following best practices, only those energy efficiency measures that are estimated to provide net bill savings are installed. Tying repayment of energy-efficiency investments to utility bills allows households to consider energy upgrades as an operational savings rather than a capital expenditure (Gillingham, Newell, and Palmer, 2009). While these programs require the participation of a utility, they also often

²³ <https://www.nclc.org/issues/prepaid-utility-service.html>

²⁴ https://www.tva.gov/file_source/TVA/Site%20Content/Environment/Environmental%20Stewardship/Air%20Quality/EPA%20Mitigation%20Projects/Smart%20Communities%20-%20Extreme%20Energy%20Makeovers%20FAQ.pdf

benefit from government support in terms of legal authority and the initial financing, as is the case with the Energy Efficiency and Conservation Loan Program (EECLP). ESPCs and ESAs also address the problem of up-front financing.²⁵

On-bill financing opportunities through utilities are expanding with minimal defaults: more than a dozen states have on-bill financing programs, and other states have pilot programs or are in the process of creating programs (Hummel and Lachman, 2018; Bell, Nadel, and Hayes, 2011; Leventis et al., 2016). The financing model would appear to be promising for owner-occupied housing, but it may not be a good fit for building owners (who take on the liability for the debt) with tenants (who typically have responsibility for the energy bills) (Brown and Wang, 2015). This is called the split-incentive challenge.

Pay-as-you-Save (PAYS) financing is an example of a tariffed on-bill financing program. It is modeled to provide 20% savings to the customer, with 80% going to repayment of cost of project. Lin (2018a) highlights the PAYS potential for success in a case study highlighting a rural Arkansas co-op. The program produced electricity bill savings to customers and benefits to implementing utilities, especially in rural areas. Through its on-bill tariff design, PAYS overcomes many barriers, such as the split-incentive challenge and the need for upfront outlays. Hummel and Lachman (2018) summarize field data reported by 12 utilities offering inclusive financing through tariffed on-bill programs in six states. Cost recovery rates in these programs have exceeded 99.9%, and no utility has reported a case of disconnection for nonpayment of PAYS charges. Their program data produces a striking picture of an inclusive financing mechanism that can reach previously underserved markets even in areas of persistent poverty.

Despite these various benefits, it is important to note that any type of property lien can have negative consequences. For example, Atlanta, Georgia, households with liens on properties were deemed ineligible for accessing a tax relief fund for legacy residents.²⁶

3.2.3 Round-Up Assistance Programs

Round-up assistance programs are designed to provide financial assistance to families and communities in need of help. It is a voluntary program in which utility customers agree to have their utility bill “rounded up” to the next whole dollar amount. The extra money paid on a utility bill, which is a donation to the round-up program fund, goes towards helping the less fortunate pay their bills and other community-based programs.²⁷ The utility designs the program such that the customer can either opt in, or opt out (i.e., customers are automatically enrolled in the program and must “opt out” in order stop contributing to the round-up assistance fund. Utility round-up programs are particularly prevalent amongst municipal and local cooperative utilities. States, however, are now introducing policies that require utilities to pro-actively inform their customers about the round-up programs if they operate on an “opt-out basis”.²⁸

The round-up funds raised from customers, often supplemented by donations from utility companies and local businesses, are put into a fund used to assist local individuals and community organizations with crucial needs. Many of those who receive financial help are low-

²⁵ <https://www4.eere.energy.gov/seeaction/publication/energy-efficiency-financing-low-and-moderate-income-households-current-state-market>

²⁶ Source: Erin Rose, Three Cubed, personal communication, August 2019.

²⁷ https://www.needhelppayingbills.com/html/operation_round_up_assistance_.html

²⁸ <https://legiscan.com/TN/text/SB0308/2019>

income families with children, seniors, and someone just facing a short-term crisis. In some cases, the charity run program also provides cash grants to community projects and local nonprofit organizations such as food pantries, volunteer fire departments, and rural ambulance services. In addition, assistance is also provided directly to individuals. Round-up programs may help with utility bills, rent, food, shelter, health care, clothing, emergency services, education, job training, and other charitable causes.

For example, under Northwest Georgia Electric Membership Cooperative's (NGEMC) Round-up Program, a monthly bill of \$70.01 is rounded up to \$71, with 99 cents going to the program that makes donations to community nonprofit organizations in the seven counties the cooperative serves.²⁹ All of NGEMC's 98,000 customers were enrolled in the program automatically at the outset of the program, and the program has awarded annual grants to individuals, families and communities in need totalling more than \$100,000 each year since 2016.

3.2.4 Prepaid Electric Services

Prepaid services are emerging in many product areas, including prepaid gift cards, transit cards, pay-as-you-go cell phones, and pre-loaded credit cards. They allow customers to manage and budget their expenditures in advance. Many countries around the world have implemented prepaid electric services, and utilities in the U.S. are beginning to implement them, particularly municipal and co-op electric service providers. In this context, prepaid services give the customer more oversight and control over usage, but the short-term credit inherent in the post-paid model is lost (Chen, 2012).

Because prepaid electricity services do not require a deposit, they can be appealing to low-income customers. With the availability of digital meters with remote connection and disconnection capabilities, utilities can respond quickly to a customer's account status, reducing the time required to turn service on and off, thereby reducing disconnection times, and with advance alerts from the utility, the customer can quickly replenish the account and avoid service shut-off.

At the same time, with increased smart meter deployment, there is a potential for increased disconnections. Prior to smart meters, each disconnection required a costly physical trip to the meter. Smart meter technologies allow utilities to disconnect customers remotely (Verclas and Hsieh, 2018).

It has been argued that prepaid service generally costs the distribution utility less than postpaid service because it reduces the utility's carrying costs, uncollectible accounts, and collection costs (Chen, 2012). Reflecting this fact, the National Association of State Utility Consumer Advocates (NASUCA) passed a resolution advising utilities that "Rates for prepaid service are lower than rates for comparable credit-based service..."³⁰ Data on the adoption of prepaid service and its impact on rates and disconnection times are difficult to obtain.

²⁹ <https://www.ngemc.com/ORU>

³⁰ <http://nasuca.org/nwp/wp-content/uploads/2014/01/NASUCA-2011-3.pdf>

3.2.5 Payment Plans

Payment plans allow customers in arrears to pay off their debt over time. State regulations typically require utilities to offer payment plans to customers who are in arrears and at risk of disconnection (Chen, 2012). Customers must repay their arrearage over a predetermined number of months, provide a down payment, and pay a minimum towards their electricity bill. Such payment plans often are based on the amount that the customer owes and do not consider the ability of the household to pay. As a result, the customer debt levels can continue to increase (Verclas and Hsieh, 2018).

In addition, there is evidence that budget billing (BB) and level billing can increase consumption. Both types of billing dilute the price signal because customers do not see seasonal or monthly variations in cost (Treadway, 2018). Getachew et al.³¹ estimates that budget billing increases energy consumption by 3.8% to 4.7%, on average. Sexton (2015) found that automatic bill payments (ABP) and budget billing used by PG&E customers can cause an increase in customers' energy consumption, attributable to a loss of price salience. For low-income customers, this would mean even larger utility bills for consumers who are already struggling with high energy burdens. DNV GL provide evidence that PG&E's Home Energy Report (HER) Program at least partially claws back these increases, which suggests that ABP and BB should be coupled with HERs to combat the loss of price salience.³²

3.2.6 Disconnection Alternatives

Utility companies and their customers can benefit by reducing costs associated with shut-offs and reconnections (Hernandez and Bird, 2010). While these services and procedures are not intended to be long-term solutions to the low-income energy burden problem (Verclas and Hsieh, 2018), they can be effective in the short-run while the housing stock, HVAC equipment, and appliances are made more energy efficient.

Lack of data on the frequency and duration of utility shut-offs makes it difficult to quantify the explicit and implicit costs associated with utility disconnections. Electricity termination can have health and safety consequences, which can be particularly serious for the elderly and young children, and for those needing medical equipment. It can also cause social stigma and ultimately lead to homelessness because many landlords consider disconnection to be grounds for eviction. While some states collect data on utility shut-off and disconnection, for privacy reasons, the data usually only includes the number of accounts disconnected, without indicating whether a limited number of accounts are being disconnected multiple times or if a large number of accounts are getting disconnected and reconnected just once (Verclas and Hsieh, 2018).

The EcoPinion Consumer Survey No. 23 conducted in 2015 (Wimberly, 2016; 2017) provides some assessment of the extent of the problem. Four percent of households with incomes less than \$50,000 had their electric service disconnected within the previous two years. This rate increased to 6% for renters and doubled to 8% for households earning less than \$25,000. With 24.4 million

³¹ . https://becccconference.org/wp-content/uploads/2017/10/sadhasivan_presentation.pdf

³²

<http://calmac.org/results.asp?flag=&searchtext=Auto+Pay&pubsearch=1&selAuthor=252&dFrom=1%2F18%2F1990&dTo=12%2F28%2F2018&yFrom=1980&yTo=2018&selPubDates=1%2F1%2F2003&selToDate=12%2F28-2018&selProgYear=&selToYear=&pubsort=1&Submit=Search>

households earning less than \$25,000,³³ this suggests that nearly 2 million U.S. households have had their electricity disconnected over the past two years.

Most utilities have disconnection policies that make households vulnerable to energy insecurity. To temper the effects of disconnections, most states have policies that protect households by setting procedures consistent with the 1978 case of *Memphis Light, Gas and Water v. Craft* (436 U.S. 1, 1978).³⁴ The U.S. Supreme Court ruling recognized that “The customer's interest in not having services terminated is self-evident, the risk of erroneous deprivation of services is not insubstantial, and the utility's interests are not incompatible with affording the notice and procedure described above.”³⁵ The U.S. Supreme Court has also ruled that all customers have a constitutional right to be given notice prior to termination of utility service.³⁶ Though a minimum level of notice is required, the length of notice and notice procedures vary widely across states. Robust notice policies could protect customers from being disconnected and alert them of their duty to pay for utility service, but delivery is complicated by factors such as language barriers and an inability to reach customers when phone and internet access are unavailable, which is often the case in low-income households.

States typically provide one or more types of disconnection limitations (Verclas and Hsieh, 2018). They range from being date based (to cover winter months), temperature-based, or tied to the need for medical equipment such as nebulizers, life support machines, and dialysis machines.

These procedural protections are not long-term solutions to the low-income energy burden problem. They do not provide financial support or other assistance to provide low-income customers with a chance to overcome debt to the utility in the long term. Additional policies are needed to help customers maintain energy access.

3.3 FEDERAL PROGRAMS AND POLICIES

Finding: At least four federal programs have missions related to low-income energy burdens, with varying levels of inter-agency coordination.

The dominant low-income federal programs and policies are the Weatherization Assistance Program (WAP) operated by the DOE and the Low Income Home Energy Assistance Program (LIHEAP) operated by the U.S. Department of Health and Human Services (HHS). In addition, EECLP, managed by the Rural Utilities Service for the U.S. Department of Agriculture (USDA), and the Low-Income Housing Tax Credit (LIHTC) Program run by the U.S. Housing and Urban Development (HUD) and supported by the US Treasury are also described because of their pertinence to low-income households.

3.3.1 DOE Weatherization Assistance

DOE’s Weatherization Assistance Program was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of this Program is to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-

³³ <https://www.statista.com/statistics/203183/percentage-distribution-of-household-income-in-the-us/>

³⁴ <https://supreme.justia.com/cases/federal/us/436/1/>

³⁵ *Mathews v. Eldridge*, 424 U. S. 319. Pp. 436 U. S. 16-19.

³⁶ <https://supreme.justia.com/cases/federal/us/436/1/>

income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with a high energy burden (see 10 CFR 440.1 and the discussion of it in Carroll, Kim, and Driscoll, 2014). The program treats single family and mobile homes, and multifamily buildings in all climate zones.

WAP provides grants to U.S. states, territories, and tribes, which then provide grants to local weatherization agencies to weatherize income-eligible low-income homes. These Grantees demarcate their own eligibility criteria, subject to WAP restrictions. The federally stipulated guideline is 200% of the Federal Poverty Level (FPL) or 60% State Median Income. LIHEAP uses a lower income threshold (150% FPL), and utility low-income programs tend to match WAP or LIHEAP, although they may qualify households up to 80% AMI and may also have moderate-income programs.

Households that receive Supplemental Security Income or Temporary Assistance for Needy Families (previously called Aid to Families with Dependent Children) are automatically eligible to receive weatherization services. Per WAP guidance, states give preference to:

- People over 60 years of age
- Families with one or more members with a disability
- Families with children
- Those with a high energy burden
- Those with high energy usage

As noted earlier, bill assistance provides a critical service to low-income households in crisis situations. Weatherization reduces energy usage and thereby decreases energy costs over the long term. Weatherization provides a longer-term solution to energy burden by addressing insulation, air infiltration, baseload energy use, and energy-efficient appliances to make homes more energy efficient. Since 1979 through the Weatherization Assistance Program and other leveraged funding, DOE has funded or otherwise supported energy-efficiency improvements and minor associated repairs for more than 7 million low-income households (Hoffman, 2017).

“Professionally trained weatherization crews use computerized energy assessments and advanced diagnostic equipment, such as blower doors, flue-gas analyzers, and infrared cameras to create a comprehensive analysis of the home to determine the most cost-effective measures appropriate and to identify any health and safety concerns associated with the energy retrofits.

Weatherization providers also thoroughly inspect households served to ensure the occupant’s safety, check for indoor air quality, combustion safety, and carbon monoxide, and identify mold infestations – which are all indications of energy waste. The auditor creates a customized work order, and trained crews install the identified energy efficient and health and safety measures.”³⁷ 100% of units served under WAP receive an inspection from a certified Quality Control Inspector who ensures all work is completed correctly and that the home is safe for the occupants. Additionally, State WAP Grantees inspect 5-10% of these units, providing an additional layer of quality assurance.

³⁷ https://nascsp.org/wp-content/uploads/2017/09/WAP_ProgramOverviewFactSheet_3.16.17.pdf

In 2015, utilities and states supplemented DOE funding by providing an additional \$883 million, or \$4.62 for every dollar invested by DOE.³⁸ This estimate includes utility funds, and any state or local funds that were coordinated with DOE's WAP. The National Association of State Community Services Programs (NASCSP) tracks the leveraging of each state; more information on state LIHEAP transfers can be found in the HHS LIHEAP Clearinghouse Database.³⁹

3.3.2 LIHEAP Bill Assistance

LIHEAP bill assistance directly compensates some of the cost of energy burden for qualifying households. It is the primary source of bill assistance to low-income high-energy burden areas. LIHEAP began in response to the increasing price of utility bills in the 70s, and the inability of low-income families to safely live in their homes because they could not afford to pay these bills. It is funded by the federal government, where funding for the program is dependent on the federal budget. HHS and the Office of Community Service within the Administration for Children and Families are the governing agencies over LIHEAP. Grantees must submit annual reports to HHS in order to participate in LIHEAP programs. They are given a block grant to help low-income families. Usually the parameters on how these households are assisted are very broad, but most of the funds are used for two-party checks between the bill payer and the utility company.

The assistance is meant to cover those with the lowest of incomes and relatively highest energy bills. According to the National Energy Assistance Director's Association (NEADA), in 2015, LIHEAP provided essential heating assistance to 6.9 million households, and essential cooling assistance to about 996,000 households. In 2009, LIHEAP was budgeted \$5.1 billion, which was the most it has been in history. LIHEAP's recent annual budgets of about \$3 billion is only able to serve about 20% of the eligible households in the country (Drehobl and Ross, 2016). The most common reason for not applying for bill assistance is a lack of awareness of assistance programs and confusion over how to apply (Treadway, 2018).

Weatherization funding is also available from LIHEAP. Up to 25% of LIHEAP appropriations can be spent on weatherization at the discretion of the authorizing state agency. The LIHEAP Statute⁴⁰ requires that grantees receive a state waiver to increase the maximum from 15% to 25%.⁴¹ NASCSP tracks the leveraging of each state.⁴² Its most recent funding report estimates that in FY 2017, the \$223.5 million of DOE WAP funding leveraged \$423.1 million of LIHEAP funding and \$225.6 million of other funding, mostly from utilities (\$138.3 million).⁴³

HHS requires grantees to have a plan on how to use LIHEAP funds for weatherization and the funds must be expended in accordance to the plan. Grantees can choose to administer the LIHEAP funds according to: entirely DOE WAP rules, entirely LIHEAP rules, mostly LIHEAP rules, or mostly DOE rules.⁴⁴ LIHEAP weatherization investments must be for cost-effective,

³⁸ https://nascsp.org/wp-content/uploads/2017/09/WAP_ProgramOverviewFactSheet_3.16.17.pdf

³⁹ https://liheappm.acf.hhs.gov/data_warehouse/index.php?report=homepage

⁴⁰ <https://liheapch.acf.hhs.gov/pubs/liheapstatute.htm>

⁴¹ <https://liheapch.acf.hhs.gov/delivery/components.htm>

⁴² https://nascsp.org/wp-content/uploads/2019/02/NASCSP-2017-WAP-Funding-Survey_FINAL_2.9.-2019.pdf

⁴³ https://nascsp.org/wp-content/uploads/2019/02/NASCSP-2017-WAP-Funding-Survey_FINAL_2.9.-2019.pdf See Tables 1 and

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⁴⁴ <https://neuac.org/wp-content/uploads/2018/07/1B-Burrin.pdf>

residential weatherization measures or other energy-related home repairs that do not constitute construction.

In about half of the U.S. states, WAP and LIHEAP are located in the same office. The LIHEAP/WAP relationship is valuable. For example, tracking WAP deferrals can be used to effectively target LIHEAP funds and LIHEAP recipients with high energy burden can be directly referred to WAP for services.⁴⁵

3.3.3 Other Federal Programs and Policies

At least two additional federal initiatives have a strong direct impact on the energy burden of low-income households: The Energy Efficiency and Conservation Loan Program (EECLP) operated by the USDA and the LIHTC tax credit monitored by the Internal Revenue Service (IRS). EECLP provides loans to finance energy efficiency and conservation programs of rural electric cooperatives that serve towns or unincorporated areas with no more than 20,000 inhabitants.⁴⁶ Eligible utilities can borrow money tied to Treasury rates of interest and re-lend the money to develop new and diverse energy service products within their service territories. The borrowed funding must be used to improve energy efficiency or encourage the use of renewable energy fuels for demand-side management, including solar PV systems, energy audits, community awareness and outreach, as well as consumer education. For instance, several utilities have used EECLP funds to support the Pay As You Save[®] (PAYS[®]) financing programs described by Lin (2018a).

State and local housing finance agencies have incorporated green building rating systems and associated funding into the construction and retrofit practices of public housing. The federal government spends about \$6 billion annually on the LIHTC program, which has supported more than 2 million housing units to date.⁴⁷ An analysis of units participating in LIHTC in Virginia concluded that they used 12.5% less energy than non-participating units. “The savings equate to 9.3%, 5.6%, and 3.5% of annual income for extremely low-income, very low-income, and low-income households” (Zhao et al., 2018, p. 559). At the same time, Reina and Kontokosta (2017) note that subsidized housing is less efficient than comparable private-sector housing, perhaps as a result of limited public funding for maintenance and upgrades. Low-income households living in subsidized or public housing units are eligible for participation in WAP.

3.4 STATE PROGRAMS AND POLICIES

Finding: States are using minimum requirements and adders to cost-effectiveness tests to promote greater investment in low-income energy programs.

Many State Energy Offices play active roles in extending energy-efficiency benefits and other energy services to low-income customers. The strong roles that States are playing are described

⁴⁵ <https://neuac.org/wp-content/uploads/2018/07/1B-Burrin.pdf>

⁴⁶ <https://www.rd.usda.gov/programs-services/energy-efficiency-and-conservation-loan-program>

⁴⁷

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/PP_Incorporate%20EE%20RE%20Standards%20as%20a%20Criterion%20in%20Tax%20Credits_FINAL_3.pdf

on the Clean Energy States Alliance (CESA) website.⁴⁸ The website also has an array of CESA guides, including:

- [Bringing the Benefits of Solar Energy to Low-Income Consumers](#) by Bentham Paulos of Paulos Analysis
- [Publicly Supported Solar Loan Programs: A Guide for States and Municipalities](#) by Travis Lowder of the National Renewable Energy Laboratory
- [Solar+Storage for Low- and Moderate-Income Communities: A Guide for States and Municipalities](#) by Todd Olinsky-Paul.

State and regional resources used to fund these initiatives include the Regional Greenhouse Gas Initiative (RGGI), State Energy Program (SEP), Qualified Energy Conservation Bonds (QEBS), state revolving loan funds, state treasury funding, general obligation bonds, utility ratepayer funds, and environmental settlements funds.

Berg and Dreihobl (2018) conducted a survey of 40 of the U.S. states, and concluded that state regulators and State Energy Offices can play a key role in encouraging utilities to carefully consider and expand the role of low-income energy-efficiency programs in their program portfolios. A mix of different strategies have been used. Key among these are (1) setting goals that require minimum levels of expenditure or savings for low-income energy-efficiency programs, and (2) special cost-effectiveness testing and provisions that give extra credit for low-income energy-efficiency accomplishments.

State requirements for goal setting include spending thresholds for low-income energy-efficiency programs, customer participation goals, and savings targets for low-income energy-efficiency programs. Special cost-effectiveness testing and provisions include cost-effectiveness exemptions, quantifying non-energy benefits, and coordination of ratepayer-funded low-income programs with WAP services. While a wide array of diverse state policies is itemized by Berg and Dreihobl (2018), the authors also note that 14 of the 15 states with the highest poverty rates do not have either type of policy; many of these states are located in the southeastern U.S.

An increasing number of states are also launching initiatives to facilitate distributed electricity that can contribute to grid resilience. Evens (2015) envisages a future utility-based model where even low- and middle-income households have the option of purchasing power outside the grid, thereby reducing the demand for grid electricity.

3.4.1 Minimum Requirements for Low-Income Energy Programs

Based on a survey conducted in 2017 by the American Council on an Energy-Efficient Economy (ACEEE), more than 20 states have spending or savings requirements for their low-income energy-efficiency programs (Berg and Dreihobl, 2018).

In some states, minimum requirements are set by public utility commissions. For instance, one of the most aggressive quotas was set by California's Public Utilities Code Section 382(e) to provide low-income energy-efficiency measures to 100% of eligible and willing customers by 2020 (Berg and Dreihobl, 2018). In New York, the Public Service Commission ordered NYSERDA to invest at least \$234.5 million of Market Development funds in Low-to-Moderate

⁴⁸ <https://cesa.org/projects/low-income-clean-energy/>

Income (LMI) initiatives for three years beginning in 2016. Thus, the impetus for these minimum requirements can come from state regulators.

State legislators can also be influential. For example, the Illinois Future Energy Jobs Act (FEJA) directed utilities to implement designated levels of low-income energy efficiency. Ameren Illinois Corporation (AIC) was required to spend at least \$8.35 million per year (Simms and Casentini, 2018). AIC established a company-wide commitment to increase its energy-efficiency spending, helping underserved communities to participate in the energy-efficiency economy by solidifying relationships with local partners and community-based organizations.

3.4.2 Adders to Cost-Effectiveness Tests for Low-Income Energy Programs

The type and level of cost-effectiveness tests applied to state low-income programs are key factors guiding investment levels. In contrast to traditional residential efficiency programs, low-income programs often seek to address a wider range of challenges beyond simply achieving energy savings; these can include health and safety issues, home durability, arrearage reduction, and electricity terminations and reconnections. For this reason, low-income programs are sometimes not held to the same cost-benefit requirements or thresholds as other types of residential efficiency programs.

A wide range and variety of approaches to evaluate the cost-effectiveness of low-income programs and program measures exists among states. One such approach to give preferential treatment to low-income energy programs, is to exempt the programs entirely from cost-effectiveness tests. Eleven states have specific regulatory or legislative language that formalizes this practice (Berg and Dreihobl, 2018). For example, the New Jersey Board of Public Utilities (NJBPU) does not require the low-income Comfort Partners Program to meet any cost-effectiveness requirements. In Minnesota, utilities may opt-out of utilizing cost-effectiveness tests. Minnesota statute 216B.241 directs that “costs and benefits associated with any approved low-income gas or electric conservation improvement program that is not cost effective when considering the costs and benefits to the utility may, at the discretion of the utility, be excluded from the calculation of net economic benefits for purposes of calculating the financial incentive to the utility.”

In other states, commonly used cost-effectiveness screening types for low-income programs include the utility cost test (UCT), total resource cost test (TRC), and the societal cost test (SCT), each tailored by regulators and program administrators to meet state-specific policy priorities or goals. An increasing number of states have taken steps to quantify the value of low-income non-energy benefits, while requirements setting specific savings targets for the low-income sector are less common (Berg and Dreihobl, 2018). For example, Vermont utilizes the societal cost test as their primary test. A 15% adjustment for non-energy benefits is applied in addition to the cost-effectiveness screening tool for low-income customer programs. The Delaware Energy Efficiency Advisory Council approved the Evaluation, Measurement and Verification (EM&V) subcommittee’s proposed estimates of low-income non-energy benefits, which took effect in 2017.⁴⁹

In Pennsylvania, under the Low-Income Usage Reduction Program (LIURP) natural gas utilities are required to devote 0.2% of company revenues towards LIURP services. Electric utilities

⁴⁹ <http://www.dnrec.delaware.gov/energy/Documents/EMVRegs.FINAL.pdf>

collect LIURP funds through a residential distribution cost included in the rates of all residential electric customers. LIURP funding levels are set over three-year periods as part of a utility's Universal Service Plan, which must be approved by the Pennsylvania PUC. Utilities adjust program funding levels for LIURP based on an assessment of the needs of their customer population. LIURP Weatherization measures are selected on the basis of simple payback recovery periods. A simple payback recovery period of seven years or less is required for most measures. Some other measures must meet a twelve-year simple payback recovery period: sidewall insulation, attic insulation, furnace replacement, water heater replacement and refrigerator replacement (Southworth, 2011).

3.5 LOCAL GOVERNMENT, COMMUNITY-BASED, NGO, AND PRIVATELY FUNDED PROGRAMS

Local and community low-income energy programs often focus on opportunities for stimulating economic development, creating liveable-wage jobs, meeting local environmental and sustainability goals, and increasing prosperity by expanding and deepening local collaborations and initiatives. For example, Donovan et al. (2018) used the Wealth Works Value Chain approach to design such programs for communities in upstate New Hampshire. The "Wealth Works" approach was created with funding from the Ford Foundation. It involves value chain coordinators to assist in solving local issues by developing an understanding of the various components of a service, developing and transforming markets, and thereby enhancing a community's prosperity. When applied to energy efficiency, a project would gather information and work with four aspects of the value chain – energy demand, service providers, outside providers and energy supply.

Shoemaker et al. (2018) highlight six energy efficiency programs serving rural areas. Community-based implementation strategies such as "Weatherize" campaigns are overcoming market barriers and accelerating the adoption of energy efficiency in low-income rural communities, Native American villages, and other underserved areas in Northern New England and Alaska (Winner et al., 2018). They are typically supported by loan and rebate programs that resonate in rural areas.

Another trend identified at the local level is the use of environmental settlement funds to support local energy efficiency assistance programs. In Tennessee, the Bristol Energy Efficiency Assistance Program was announced as a part of an environmental settlement in 2014. The program involved coordination between local economic development and community assistance program officials in conjunction with state environmental regulators. Tennessee's State Energy Office worked in partnership with local economic and community development officials to oversee the program's implementation process, coordinate measures and enrolment using existing community assistance programs, and served as technical advisors to local program administrators throughout the project.⁵⁰ The Bristol Energy Efficiency Assistance Program partnered with an existing program in the City of Bristol that provided housing repair assistance

⁵⁰ <https://www.tn.gov/environment/program-areas/energy/state-energy-office--seo-/programs-projects/programs-and-projects/special-energy-projects0/redirect---special-energy-projects/city-of-bristol-energy-efficiency-assistance-program.html>

to economically disadvantaged homeowners. Through this partnership, a ready-made qualified group of people could be targeted for support under the King Consent Decree funding.⁵¹

Many cities are developing climate change adaptation and mitigation plans, and many of them consider their impacts on low-income households alongside other equity issues (Barbier, 2014). For example, in Portland, Oregon, the incorporation of equity considerations in the city's climate action plans resulted in a "Climate Action through Equity" plan in 2016. Towns and cities have also organized Weatherize campaigns, modeled after Solarize campaigns, where goals are set and providers are pre-approved in order to foster local participation.⁵²

NGOs operate energy and affordable housing initiatives at all scales from the local to the international. For example, the National Center for Healthy Housing (NCHH,) provides guiding documents related to safety, ventilation, moisture control, and thermal comfort, all of which impact energy usage and are particularly pertinent to low-income housing where indoor air quality problems can be severe.⁵³ The magnitude of philanthropic funding of the totality of these initiatives has not been estimated in the last decade of searchable publications in the Web of Science.

⁵¹ <https://www.tn.gov/environment/program-areas/energy/state-energy-office--seo-/programs-projects/programs-and-projects/special-energy-projects0/redirect---special-energy-projects/city-of-bristol-energy-efficiency-assistance-program.html>

⁵² <http://www.greenenergytimes.org/2018/12/17/weatherize-campaigns-spread-across-new-hampshire/>

⁵³ <https://nchh.org/information-and-evidence/learn-about-healthy-housing/healthy-homes-principles/>

4. THE IMPACTS AND COST-EFFECTIVENESS OF LOW-INCOME ENERGY PROGRAMS AND POLICIES

This section describes the impacts and cost-effectiveness of the many different types of programs and policies that address the energy burdens of low-income households.

4.1 ESTIMATES OF COSTS, BENEFITS, AND COST EFFECTIVENESS

Extensive assessments of the cost-effectiveness of DOE's Weatherization Assistance Program and utility low-income energy efficiency programs have been conducted, and their results are summarized here. The performance of state, local government, and community-based programs has also been documented in case studies and comparative assessments. Some have also benefited from the same level of systematic assessment typical of national programs, including field surveys, inspections, and utility-bill analysis.

4.1.1 Electric and Gas Utility Low-Income Programs

Finding: Low-income energy efficiency programs operated by electric and gas utilities cost more to implement per household and often deliver more critical service given the lack of resources of participants. Based solely on their energy cost savings, these programs are less cost-effective than energy-efficiency programs that serve higher income groups. Low-income energy programs ensure low-income households can benefit from ratepayer funding that they help pay for but would otherwise not benefit from.

The literature documents that the average cost of saving electricity is higher for low-income programs than for other residential, commercial, and industrial programs. For example, Hoffman et al. (2018) examined data spanning 815 program-years of low-income efficiency programs operated by electric utilities from 2009-2015. Their assessment of cost-effectiveness distinguishes between the program administrator cost per kWh saved and the metric when participant costs are included in addition to the program administrator cost. Across all 815 utility programs in the U.S., saving-weighted average program administrator's cost of saved electricity is \$0.025 (in \$2016) / kWh, and this rises to \$0.050 when participant costs are added. For low-income programs, the average program administrator's cost of saved electricity is \$0.105 (in \$2016) / kWh, and this rises to \$0.145 when participant costs are added (Figure 4.1). Low-income participants contribute about 1.3 cents per kWh saved, which is less than in other programs that serve higher income households. This low contribution by low-income customers is consistent with their limited access to financial resources.

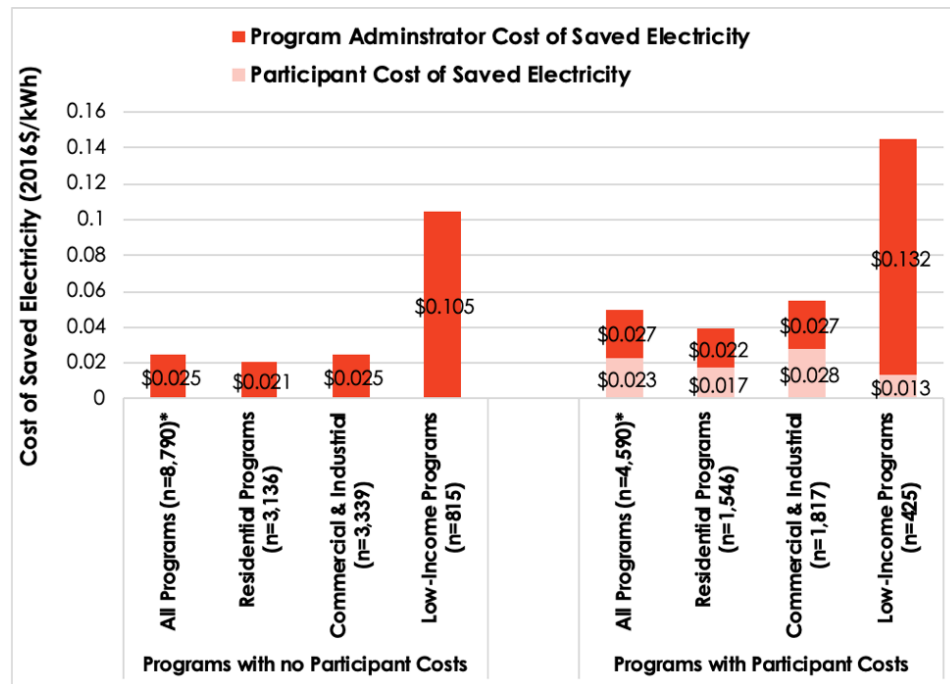


Figure 4.1. Cost of saving electricity in utility energy-efficiency programs.

Source: Redrawn from data published in Hoffman et al. (2018)

4.1.2 DOE Weatherization Assistance Program

Finding: The savings-to-investment ratio of WAP is favorable based on the value of its energy savings alone. The value of the non-energy benefits of WAP and other low-income energy programs are significant.

DOE (2015), Tonn et al. (2014a) and Tonn, Rose, and Hawkins (2018) describe two WAP impact evaluations: one focused on 2008 (before ARRA) and the other focused on 2010, after the Program's funding was significantly boosted by ARRA. The WAP impacts include savings of fossil fuels and firewood as well as electricity (Table 4.1).

The 2008 program supported the weatherization of 97,965 units and reduced energy costs by \$340 million over the lifetime of its installed measures. With an average household energy savings of \$4,243 and energy measure costs of \$2,899, the savings-to-investment ratio (SIR) for the energy measures is 1.4. The 2010 program supported the weatherization of about 340,000 units, reducing energy costs by \$1.2 billion and resulting in an energy-based SIR of 1.0. Environmental, health, and household related benefits were found to be significant in both program evaluations. The 2008 program evaluation results are indicative of the program generally and today because the funding during the ARRA period was an order of magnitude greater than normal and occurred in a condensed timeline.

When communities can enjoy more energy-efficient utilities, they derive a variety of benefits including improved public health, higher investment in the local economy, poverty alleviation and sometimes job creation with weatherization policies.

Table 4.1 Summary of benefits from weatherization assistance program in 2008 and 2010

(Sources: Tonn et al., 2014a; DOE, 2015; Tonn et al., 2018)

Program Wide Benefits for All Housing Types		
	2008	2010
Total Homes Weatherized	97,965	340,158
Average Cost per Weatherized Home	Total Cost: \$4,695 DOE Investment: \$2,301	Total Cost: \$6,812 DOE Investment: \$5,926
Average Energy Measure Costs	\$2,899	\$3,545
Energy Savings Per Household (Present Value)	\$4,243	\$3,190
Total Energy Savings (Present Value)	\$340 million	\$1.2 billion
Savings-to-Investment Ratio	1.4 ⁱ	0.98 ⁱⁱ
Total Benefits per Household Including Health & Safety (Present Value)	\$13,550	\$13,167
Carbon Reduction	2.25 million metric tons	7.38 million metric tons
Savings-to-Investment Ratio for Submarkets		
	2008	2010
Single-Family Homes	1.72	1.12 (0.82-1.53)*
Mobile Homes	1.03	0.79 (0.66-0.79)
Small Multifamily	1.60	
Large Multi-Family (New York City only)	1.82	0.67 (0.55-0.84)

ⁱ These values include funding from some non-DOE sources that are not uniformly subject to DOE's Savings to Investment Ratio (SIR) requirement that is used to guide the measures that are installed. These funds are often used for more costly energy measures that result in lower SIRs for the combined funds.

Tonn et al. (2018) found that the energy savings vary by housing type, with site-built homes saving more than mobile or multi-family homes. Costs and benefits were also influenced by fuel type and climate zone.

A limited number of studies estimate the potential of a “rebound effect” in low-income houses. The concern is that participants in energy-efficiency programs may increase their use of energy services after their home is retrofitted, reducing or potentially negating any energy savings. In an evaluation of households participating in WAP, Tonn et al., (2015) conclude that this effect is negligible based on surveys of behavior pre- and post-weatherization.

4.1.3 State Green Building Policies

Longitudinal analysis has been used in a few studies to examine the time effects of state green building policies (operating independently of WAP) on the energy performance of low-income housing units. In one case, Zhao et al. (2018) evaluated monthly energy use data over three years from 310 residential units across 16 developments in the State of Virginia and conducted profile analysis and multivariate analysis of variance (MANOVA). Their results estimate financial savings of \$648 per year due to reduced energy usage in green buildings. These savings equate to 9.3%, 5.6%, and 3.5% of annual income for extremely low-income, very low-income, and low-

income families, respectively, suggesting that green building incentives and practices can enable housing with affordable energy systems. The broader goal of affordable housing is a much bigger issue tied to regional economics, housing vintage, and many other factors. Energy is just one piece of the poverty puzzle; making energy more affordable and sustainable is important but not a complete solution to the poverty problem.

4.1.4 Community Partnerships

Local partnerships in some states and communities, such as those supported by the DOE initiative called the Clean Energy for Low Income Communities Accelerator (CELICA), have been designed to take a more holistic approach to energy affordability. It required partnerships across different levels of government agencies, where DOE provided assistance to states and local governments on the design and implementation of low-income energy programs. CELICA not only provided support to reduce energy burdens, but also provided tools for managing and monitoring progress (DOE, 2017). Taking a broader perspective, CELICA not only leveraged the Weatherization Assistance Program and its network of providers to expand access to energy efficiency for low income households beyond what federal funding could address, but also promoted distributed renewables to provide stability from rising energy costs, promoted economic development, and improved the environment.

4.2 UNDER-SERVED LOW-INCOME COHORTS

Evidence suggests that three cohorts have been under-served by efforts aimed at addressing the high energy burden of low-income households: multifamily and rental markets, rural communities, and manufactured and mobile homes.

4.2.1 Multifamily and Rental Markets

Finding: The multifamily low-income market has been difficult to reach with traditional energy-efficiency programs due partly to misalignment of incentives. New program designs that address split-incentives and incorporate strong community engagement can help reach multifamily markets. Strong community engagement can expand participation rates and enhance the success of low-income energy programs. Public-private-philanthropic-partnerships and interagency coordination and leveraging can reduce energy costs for low-income households while also delivering non-energy benefits.

Multifamily buildings are home to nearly 25% of the U.S. population and more than half of low-income households (Hernandez et al., 2016; Corso, Garascia, and Scheu, 2017; Frey et al., 2015).⁵⁴ Based on the 63,166 housing units occupied by low-income households that were examined by Hernandez, et al. (2016), the percentage of low-income households living in multifamily housing is 51.9%. Specifically, 32,824 (36.6%) of the 63,166 units were either an attached house or were located in a small apartment building, and 9,725 (15.4%) were located in a large apartment building. For a variety of reasons including high land values, cities and urban areas have a disproportionate number of multifamily buildings (Hernandez and Philips, 2015).

With high rates of various vulnerabilities and a lack of access to housing improvements, households in low-income multifamily housing face disproportionate health and financial

⁵⁴ <https://www.energy.gov/eere/slsc/maps/lead-tool>

challenges (Fabian et al., 2012; Waite et al., 2018) At the same time, these households are often underserved by traditional energy-efficiency programs (Ross, Jarrett, and York, 2016; Berkland et al., 2018). In Program Year 2008, WAP funds supported the weatherization of 97,965 units; 23% of these lived in multifamily buildings (18% large and 5% small multifamily structures) (Tonn, 2014a). These markets have been hard to reach by traditional utility and government programs (Corso et al., 2017; Henderson, 2015). A major reason is that incentives are misaligned as a result of a “principal-agent” or “split-incentive” problem. When tenants pay the energy bills, the building owner may not be motivated to invest in improvements because the bill savings accrue to occupants (Reina and Kontokosta, 2017).

Considering their high concentration, these markets represent a significant potential for energy and cost savings and for improving people’s lives including the quality of the air they breathe (Chant, Schaaf, and Ast, 2016; Henderson, 2015; Frey et al., 2015). Further, government control over multifamily units that form part of public housing makes it possible to integrate different policies (Reina and Kontokosta, 2017). The consensus appears to be that there is a need for scaling up the energy-efficiency and related improvement programs for multifamily and rental markets (Samarripas, York, and Ross, 2017).

Different types of energy-efficiency programs have been implemented to address low-income multifamily market needs. These include programs led by utilities and NGOs; financing programs (Leventis, Karmer, and Schwartz, 2017); and data collection programs (Long et al., 2018). Several lessons can be found in the reports and studies we analyzed. Community support is particularly useful in multifamily programs (Chant et al., 2016; Sanchez, Levine, and Tajina, 2018). In two cities in Ohio, Andrews and Poe (2018) found that local community involvement led to increased participation, ultimately leading to improvements in health and safety for tenants as well as landlords. Similarly, community based social marketing can increase the success of programs (Keilty, 2018). Carefully designing the incentives and utility-managed on-bill financing can help address the problem of misaligned incentives (Bird and Hernandez, 2012). Finally, by integrating energy efficiency into solar projects, energy burdens can be significantly reduced (Samarripas and York, 2018).

4.2.2 Rural America, Island Territories, and Indian Reservations

Finding: Low-income households in rural communities often spend as much as a quarter of their income on energy due partly to the low-density built environment enabled by lower land values. Assistance from local community programs and organizations are particularly critical to success in these markets.

Energy burdens in rural communities are estimated to be as high as 25% (Ross et al., 2018). Thus, rural communities may have the greatest need for energy-efficiency programs. The distribution of burdens in rural areas largely reflects the socio-demographic patterns in the rest of the country with minorities, elderly, and renter households spending a higher share of income to meet utility bills (Ross et al., 2018). This problem can be even more pronounced for island territories (Winner et al., 2018). Rural areas present unique challenges for implementing energy efficiency programs; they are less densely populated, typically have a different fuel and consumer mix, different regulatory structures, and high program implementation costs (Shoemaker et al., 2018). Lower densities can make it difficult to access energy-efficiency programs, and result in higher costs of providing infrastructure including pipeline infrastructure

to support the conversion of electricity, fuel oil, kerosene and other fuels to natural gas, which is often the least-cost fuel for home heating (Ross et al, 2018).

Native American reservations have similar characteristics and account for some of the highest rates of energy poverty in the U.S. Their un-electrified homes span the contiguous United States and Alaska (Begay, 2018a). Provision of energy access to remote areas in the reservations at affordable rates has been a challenge for the traditional electricity development model. Looking to the future, these reservations have a lot of promise because they represent 2% of the U.S. landmass but 5% of the renewable energy resources (Begay, 2018a). Harnessing these resources can be a way of rejuvenating the economies of rural communities (DeSilva, McComb, and Schiller, 2016; Donovan et al., 2018). The rooftop solar solution the Navajo Nation has adopted in collaboration with Sandia National Laboratories offers insights into how the Navajo Tribal Utility Authority's work could serve as a residential model to meet the needs of the 1.2 billion people globally who are without electrical residential power.

Several programs have been piloted and rolled out to reduce energy burdens and increase access in these communities over time. These involve direct funding from government programs, NGO involvement, and funding from charitable organizations. Different agencies are responsible for implementing these projects, including State Energy Offices, electric cooperatives, municipal or investor owned utilities (Donovan et al., 2018; Shoemaker et al., 2018).

Results and findings from pilot projects and other programs focused on rural areas show that gains from targeted rural energy-efficiency programs can be increased by using cooperatives in remote rural locations (Lin, 2018a). This is especially true if the financial support can be earmarked to meet upfront costs and to address the challenge of split incentives. Similarly, community-based programs where partnerships with NGOs is leveraged are also found to be successful (Andrews and Poe, 2018; Donovan et al., 2018). There are significant gains to be made from pooling resources from different projects to achieve economies of scale, and from training workers to operate these new systems (Souba and Mendelson, 2018). It has been estimated that strategies to tackle the energy-efficiency gap in rural and small-town America could reduce energy burdens by as much as 25% (Ross et al., 2018).

4.2.3 Manufactured and Mobile Homes

Finding: The opportunity to address the high energy burdens of low-income households occupying manufactured housing has received limited analysis and policy focus.

This oversight is related to the limited attention given to the energy-efficiency gap in rural America, where 70% of all manufactured homes are situated. Manufactured homes made up 9% of new U.S. homes in 2017 and housed more than 20 million people in total.⁵⁵ Manufactured homes consume 35% less energy than other homes due to their smaller footprint, but unfortunately residents spend 70% more per square foot on energy (Ross et al., 2018). With a median family income of \$30,000, residents of manufactured homes have higher-than-average energy burdens.⁵⁶

⁵⁵ <https://www.manufacturedhousing.org/wp-content/uploads/2017/10/2017-MHI-Quick-Facts.pdf>.

⁵⁶ <https://aceee.org/blog/2016/08/mobile-homes-move-toward-efficiency>

4.3 TECHNOLOGIES AND MEASURES INSTALLED

Finding: Health and safety upgrades are not components of most utility low-income energy-efficiency programs. Information and communication technologies such as smart thermostats support low-cost behavioral approaches to improving energy efficiency, but they tend not to be incorporated into low-income energy programs.

Through its Grantees and its network of hundreds of Subgrantees providing services at the local level, WAP installs energy efficiency measures and a limited amount of energy-related safety/health measures at no financial cost to homeowners. Air sealing and insulation are the two most common measures (Figure 4.2). Some utilities also use contractors to directly install measures. The most common measures installed by contractors under electric utility programs are lighting, air sealing, insulation, and water heater upgrades, typically at no financial cost to the household. Some utilities also offer energy-savings kits with weatherstripping, caulking, LED bulbs, and other low-cost items that homeowners can install themselves.

Drehobl and Castro-Alvarez (2017) found that the majority of cities have access to utility programs with lighting, air sealing, and insulation measures, while smart thermostats and health and safety measures were the least common program measures. In terms of cost-effectiveness, Elsawaf, Abdel-Salam, and Abaza (2013) found that that air-source heat pumps could reduce heating costs in low-income mobile homes by up to 52% when integrated in an electric strip heat system, while also improving thermal comfort in their analysis of eastern North Carolina. They also found that their benefits exceed the initial cost of installation.

Other studies have also documented co-benefits and savings from building improvements. For example, the health and financial benefits of replacing old windows with thermally efficient windows have been documented by Jacobs et al. (2016), who conclude that in addition to saving energy costs, window replacement programs can also reduce the potential exposure to lead from degraded lead paint mixed in soil and dust.

Bradshaw et al. (2016) investigate the benefits and cost-effectiveness of three types of weatherization treatments: replacing a standard thermostat with a programmable thermostat, installing attic insulation, and envelope air sealing. These treatments were modeled for the low-income housing stock of six contrasting American urban areas: Orlando, Florida; Los Angeles-Long Beach, California; Seattle, Washington; Philadelphia, Pennsylvania; Detroit, Michigan; and Milwaukee, Wisconsin. Results show that (1) regional variations have high impact on the cost-effectiveness of weatherization treatments, (2) housing stocks with substantial electric space conditioning tend to offer greater energy cost and greenhouse gas (GHG) savings, (3) the effect of a GHG price is small compared to energy cost savings when evaluating the cost-effectiveness of weatherization treatments, and (4) installing programmable thermostats is the most cost-effective treatment of the three treatments studied. This study highlights the importance of thoughtful consideration of low-income energy-efficiency program goals when selecting cities or regions to prioritize because different goals suggest different approaches.

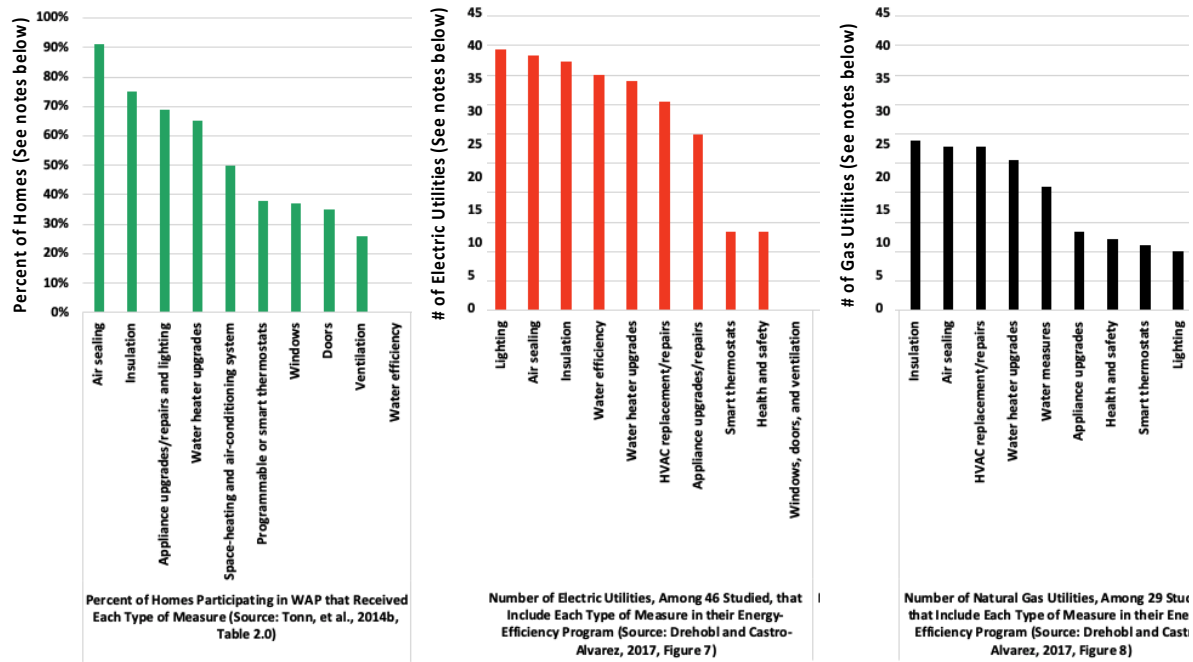


Figure 4.2. Measures installed in low-income programs.

(Source: Authors, based on data from Tonn et al., 2014b; Dreihobl and Castro-Alvarez, 2017)

Verclas and Hsieh (2018) looks at disconnection policies of utilities that make households vulnerable to energy insecurity. The data on disconnections by utilities is not easily available. The authors look at Minnesota and Iowa and identify the policies in place to help customers maintain access to energy resources.

4.4 THE ENERGY SAVING POTENTIAL OF LOW-INCOME HOUSHOLDS IN THE U.S.

In a study of the 48 largest cities in the country, Dreihobl and Ross (2016) estimate that if the low-income housing stock were brought up to the efficiency level of the average U.S. home, 35% of the low-income energy burden could be eliminated.

Focusing specifically on possible electricity savings from weatherization, Hoffman (2017) assessed the implications of pursuing energy efficiency neighborhood-by-neighborhood where low-income households are prevalent. Using data on demographics, housing types and recent savings from low-income retrofits, and assuming that households at 200% of the Federal Poverty Level are eligible, Hoffman (2017) provides rough electricity savings estimates of 51.5 billion kWh. A majority of these savings are in the South (54%) and in hot-humid climate zones (38%), where much of the nation's poverty is concentrated.

5. PROMISING PRACTICES

5.1 SOLAR ENERGY FOR LOW-INCOME HOUSEHOLDS

Finding: Expanding the technology scope of low-income energy-efficiency programs to include solar PV, smart meters, storage, and electric vehicles could significantly improve energy affordability for low-income households. Broadening finance and administrative options (e.g., on-bill program designs) could also expand savings opportunities.

Historically, affluent households have dominated the market for residential solar installations, but with expanding production and declining costs, solar systems are now beginning to reach previously underserved markets. In low-income communities, solar energy can significantly reduce energy burdens, while also generating living-wage jobs. By displacing pollution from traditional sources of energy, solar can also mitigate disproportionate negative environmental impacts on low-income communities (Franklin and Osborne, 2017). Despite these perceived benefits, disparities across the country in the adoption of solar resources continue to persist; this continuing gap can be attributed to social, political, and economic factors, as well as the structural integrity of roofs and the soft costs of running programs (Kann and Toth⁵⁷; Tidwell, Tidwell and Nelson, 2018; Gupta et al., 2018b; Zhang et al.⁵⁸; Sunter et al., 2019). Typically, there has also been a trade-off between reducing bills for low-income households and ensuring returns for utilities (Aznar and Gagane, 2018). Further, the growing adoption of solar by affluent households can potentially reduce sales for utilities and disproportionately affect the share of fixed utility costs that low-income households have to bear.

A detailed analysis of solar adoption presents some interesting patterns of diffusion of solar technology at local and household levels. In their study of solar PV in Connecticut, Graziano and Gillingham (2014) find that the number of previously installed solar systems, and characteristics of the built environment significantly predict adoption of PV systems. This corroborates findings that peer influences, community effects, and word-of-mouth strongly influence solar adoption (Bollinger, Gillingham, and Tsvetanov, 2016; Gillingham and Bollinger, 2017; Gupta et al., 2018a).

Federal and state programs focused on addressing energy poverty have traditionally helped deploy weatherization and bill assistance programs; however, coupling these services with solar financing assistance presents a potentially attractive way to more dramatically reduce the energy burden of low-income households (Ulrich et al., 2018). The Navajo Nation provides a vivid example of rooftop solar systems being installed to tackle energy poverty among its 35,000 remote off-grid Native American members, with dispersed housing, where solar PV rooftop systems are providing a viable solution to this rural electrification dilemma (Begay, 2018b).

Despite the expanding penetration of low-income solar systems, research to date has not yet fully assessed what proportion of low-income housing is suitable for solar PV or what fraction of low-income electricity needs could be met by solar systems (Sigrin and Mooney, 2018). Such assessments need to consider the barriers that make it difficult for low-income households to acquire solar resources, such as:

⁵⁷ <https://www.woodmac.com/our-expertise/focus/Power--Renewables/How-Wealthy-Are-Residential-Solar-Customers/>

⁵⁸ https://beccconference.org/wp-content/uploads/2018/10/jingjang_presentation2018.pdf

- **Access to capital and lower credit ratings.** Investments in solar installation can be prohibitive for low-income families, due to their high cost. This segment of the population can establish a power purchase agreement with a third party to avoid the high upfront cost. However, third parties are likely to reject a low-income customer if they have a low credit score.⁵⁹
- **The landlord/tenant split incentive.** Given that multifamily buildings represent a significant portion of the housing property portfolio, they present an important opportunity for the growth of rooftop solar (Inskeep, Daniel, and Proudlove, 2015).
- **Lack of information and language problems.** Low-income families for whom English is a second language can have trouble making informed decisions about solar installations because of language barriers that impede learning about the benefits of solar technologies (Paulos, 2017).
- **Housing conditions.** To install solar, roofs must have 10-15 years of remaining life, which is rarely the case in low-income housing. Structural repairs, plumbing, insulation and roof maintenance are often more pressing priorities for low-income residents.⁶⁰

The federal government's Investment Tax Credit is one of the most powerful policies currently promoting solar investments in the U.S., but it is inaccessible to most low-income households who typically have limited tax liability.⁶¹ Paulos (2017) estimates that securing a 30% credit on a \$10,000 solar installation would require a taxable income of at least \$26,000.

Traditional utility net metering and solar deployment subsidies also have issues of fairness. Under typical rate structures, net metering shifts costs from solar owners to lower-income ratepayers (Johnson et al., 2017). At the same time, the rapid deployment of rooftop solar systems has raised concerns about the fair distribution of electricity costs through rates (Franklin and Osborne, 2017). Distributed solar programs raise rates, while their subsidies go disproportionately to affluent households. Further, if not accounted for properly, increase in solar penetration can also lead to operational and financial challenges and consequently, result in reduction in the potential environmental benefits (Padhee and Pal, 2018). As with energy efficiency and electric vehicle programs, low-income households have notably low rates of participation in solar programs (Ulrich et al., 2018).⁶² A recent national assessment of residential rooftop solar technical potential estimates that low-income housing accounts for approximately 25% of the nation's total technical potential.⁶³ It should be noted that some low-income households may not be able to participate in solar programs if the building roofs are older and not structurally sound.

At the same time, because of their high levels of energy burden, low-income households are more severely impacted by rising electricity rates compared with other "non-participants" who typically have lower energy burdens. Because some form of dynamic pricing is currently available to most residential customers in the U.S., most low-income households can take advantage of them. The goal of dynamic pricing is to provide accurate price signals so that customers will be motivated to reduce their consumption during hours when the utility is

⁵⁹ http://www.gridalternatives.org/sites/default/files/Low-income%20solar%20policy%20guide%20press%20release_FINAL.pdf

⁶⁰ http://www.gridalternatives.org/sites/default/files/Low-income%20solar%20policy%20guide%20press%20release_FINAL.pdf

⁶¹ <https://www.taxpolicycenter.org/taxvox/new-estimates-how-many-households-pay-no-federal-income-tax>

⁶² <https://emp.lbl.gov/publications/income-trends-residential-pv-adopters>; <https://www.woodmac.com/our-expertise/focus/Power-Renewables/How-Wealthy-Are-Residential-Solar-Customers/>

⁶³ <https://www.nrel.gov/docs/fy18osti/70901.pdf>

experiencing high-priced peak demand. The most common dynamic pricing for residential customers is time-of-use (TOU) rates, where utilities set electricity prices for different time periods in advance. The rates for each time block are usually adjusted two or three times each year to reflect changes in the demand and wholesale market (Brown, Zhou, and Ahmadi, 2018).

For example, to accommodate for high levels of distributed generation and peak hours that are shifting from the afternoon to the evening, California has adopted default TOU rates that have shifted to later peak pricing periods. Waite et al. (2018) shows that these new TOU rate structures in California can increase energy cost burdens and have adverse consequences for low-income customers. Similarly, a randomized experiment conducted in the southwestern U.S., demonstrated that TOU rates can disproportionately increase the bills of households with elderly and disabled occupants, which, for a variety of reasons, may be less able to shift their consumption to low-cost hours of the day (White and Sintov, 2019).

The same fairness concerns would appear to apply to EV rates offered by utilities, where night-time purchasing of electricity by EV owners is offered super-off-peak pricing, which subsidizes electricity usage for those who can afford EVs.

One study of New Jersey solar data, PJM market data, and demand profiles from a PJM utility investigated rate and bill impacts of large-scale solar penetration (Johnson et al., 2017). It concluded that the fear of a utility “death spiral” and significant rate impacts may be exaggerated. Significant solar can be incorporated with only a 2% increase in non-participant bills. On the other hand, at high levels of penetration, distributed solar has the potential to alter the system peak hour which affects the allocation of costs across rate-classes. As the peak hour shifts to the evening when solar production diminishes, residential customers, in particular low-income households, face higher distribution costs. Policy makers and utilities need to be aware of these challenges in designing the next generation of rates that are better aligned with cost causality. Ronen, Gai, and Crampton (2016) find that repurposing the existing programs to cover the cost of rooftop solar could reduce electricity bills for low-income households by about \$9,000 over the lifetime of solar systems. (The authors do not discuss the maintenance and repair costs of the system.)

Programs are emerging that target barriers to solar installations for low-income households. They can be divided into rooftop solar programs and community solar initiatives.

5.1.1 Rooftop Solar Programs

“Solarize” and “Solar for All” campaigns have been popular models for promoting rooftop solar. In general, Solarize campaigns aim to remove barriers and headaches of installing solar in residences (Cook, 2014), while “Solar for All” programs typically include incentives for solar panels so that low-income households can afford to install them. Both models support the creation of “prosumers” who generate and export solar power, thereby reducing their energy bills and burden. The magnitude of electricity bill reductions depends on the utility’s net metering. Another type of program integrates solar panels into low-income home retrofits, and sometimes electric vehicles are part of the expanded program.

“Solar for All” programs typically aim to install PV systems in low-income households and to provide grants to other organizations with similar goals. For example, the Washington DC’s

“Solar for All” program is funded by DC’s Department of Energy and Environment and plans to install solar PV systems on more than 6,000 low-income homes annually with a goal of reaching 100,000 low-income households by 2032. This program helps lower the energy burden of its low-income households and contributes to accomplishing its renewable energy goals.⁶⁴

Another sizeable community-led solar aggregation and energy efficiency program is targeting low-to-moderate-income residents of Northern Manhattan (Roundtree, 2018). A community-led Energy Democracy Working Group (EDWG) selected and evaluated solar installers and is coordinating with the Housing Development Fund Corporation to reach co-op residents who are predominantly low to moderate income people of color. The project team also works with solar installers and the EDWG to promote local job creation related to the initiative.

California’s Multifamily Affordable Solar Housing Program shows that subsidized efforts can bring solar resources successfully to multifamily housing. MASH targets multifamily housing and was created under the California Solar Initiative bill enacted in 2006. Homes must be using either Pacific Gas and Electric, Southern California Edison, or San Diego Gas and Electric as their utility provider. Customers must also have an occupancy permit of two years or more. This program provides fixed, upfront payment based on the system’s potential capacity. Incentives for these multifamily homes are all Expected Performance Based Buydown (EPBB).⁶⁵ As of July 2017, the program has contributed 33.75 MW of interconnected solar capacity, successfully operated 427 projects statewide in multifamily low-income housing, and paid \$95 million in incentives to customers (Coughlin, Irvine, and Johnson, 2013).

Several case studies have shown that risks associated with installing solar on affordable housing can be mitigated by leveraging investments in energy efficiency (Samarripas and York, 2018). Two Michigan communities took advantage of additional WAP-ARRA-funding through the Sustainable Energy Resources for Consumers Grants (SERC) to expand weatherization to include solar. Their efforts concluded that renewable energy may have additional quality of life benefits to offer families beyond the cost savings (Walton, 2014). Similarly, Colorado and New York State have initiated efforts to hybridize weatherization with solar investments in WAP projects; and in a few states, LIHEAP rules allow weatherization projects to incorporate PV as an option to reduce household energy burden (Ulrich et al., 2018). Evidence of cost effectiveness of this energy-efficiency and renewable energy combination has emerged from the efforts of the Colorado Energy Office in a state with high solar irradiance. In their evaluation of the CEO’s efforts, Cook and Shah (2018a) found that regardless of the type of energy-efficiency improvements, incorporating PV as a measure to reduce the cost of electricity cuts customer bills by \$400 or more annually. (This is without taking into account the maintenance costs of the system.) Integrating electric vehicles can reduce costs further, as in the Single Family Affordable Solar Housing (SASH) pilot program (Verclas, 2018), and Vermont has also hybridized all three types of measures – energy efficiency, solar, and electric vehicles – with home energy storage. Further, as in the case of energy efficiency programs, community organizers can also play a role in encouraging pro-social behaviors (Kraft-Todd et al., 2018; Wolske, Stern, and Dietz, 2017).

⁶⁴ <https://doee.dc.gov/solarforall>

⁶⁵ The EPBB is an up-front incentive payment where the incentive amount is adjusted to reflect verifiable system capacity as well as the effect of system orientation and shading on energy production. https://www.cleanpower.com/wp-content/uploads/2012/02/008_EPBB_IncentiveStructure.pdf

Finally, the fact that solar is approaching cost-parity in many areas and can improve the resilience of housing, has led to its increasing role in disaster recovery efforts across the country including the Caribbean Islands. The FEMA Disaster Recovery Act and HUD Community Development Block Grant-Disaster Recovery (CDBGDR) program now have more funding dedicated to solar installations in light of this. DOE and HUD are also implementing solar and energy storage in disaster prone areas for low-income households (Source: DiRamio, Personal Communication, September 2019).

5.1.2 Community Solar Programs

Community-solar helps low-income households take advantage of solar projects by allowing them to purchase a small portion of as little as one panel of an offsite, local solar array in exchange for reductions to their utility bill for the entire life of the solar system (Booth, 2014). Sometimes called “shared solar”, community solar refers to local solar facilities shared by multiple subscribers. Community solar is particularly suitable for low-income renters and multifamily residents who can access solar via two alternative business models (IREC, 2018). With on-site shared solar, energy generation credits can be purchased from a single solar system that is shared virtually among multiple tenant accounts. With off-site shared solar, multiple remote customers can receive credits on their various utility bills for the shares they own in a common system. In sum, community solar provides three benefits. It can make solar accessible to homeowners without a rooftop and to renters, it can be easily transferable, and it may reduce replacement risks for on-site solar systems.

The state level policies on solar vary across states. While many states have some type of policy initiative to support the adoption of community solar, most of these are one-off policies rather than state-wide programs. In the absence of state-led programs, voluntary and utility-led programs are unlikely to reach underserved communities (Vote Solar, 2018). Community solar programs in the U.S. have at least four distinct ownership and management arrangements. In a utility-sponsored model, shares are offered to electric ratepayers. In a special purpose entity model, community investors can receive a return on investment (ROI) and offset their personal electricity use. In a non-profit model, donors contribute to a non-profit that owns the community installation. In a community-shared model, a third-party solar vendor owns the facility and community members sign up to be a part of the solar campaign (Coughlin et al., 2013). Several of these have served low-income multifamily residents, including one non-profit model used by the Co-op Power in New York and two utility-sponsored models including California’s Multifamily Affordable Solar Housing (MASH) and a Maryland PSC pilot program. Like many Solarize programs, Solarize Mass-Somerville is a community solar model that does not have an income qualification (Coughlin et al., 2013). It is available for low-income households, who otherwise would be unable to purchase rooftop solar.

Thus, administrators of low-income programs are learning from models that have successfully served higher-income customers and are creating new types of business models that are adapted and evolved to meet the needs of low-income households (Chan, Ernst, and Newcomb, 2017; Cook and Shah, 2018b; Heeter et al., 2018). However, the applicability of these strategies to low-income markets depends on the type of housing and the ownership status. As a result, Cook and Bird (2018) identified 13 different financing options that could be deployed for low- and moderate-income customers, each with its own unique features and impacts. Policymakers need to weigh the pros and cons of each type when considering applicability to their low-income

communities. IREC (2016) recommends using alternative financing tools such as anchor subscribers and back-up guarantees, direct and tax incentives, loan programs and credit enhancements, and low-cost public financing.

An interesting finding is that utilities are motivated to develop community solar not only to satisfy consumer demand or meet regulatory requirements for renewable energy, but also to alleviate revenue losses related to residential solar PV adoption (Funkhouser, et al., 2015). When net metering of rooftop solar power is set at retail rates, homeowners with rooftop systems pay significantly lower bills and do not pay for all of their associated fixed costs that the utility incurs. In a sense, they become “free riders”, relying on non-participants to cover the fixed charges that they once pay for before installing their solar system (Funkhouser, et al., 2015). Community solar can be designed to keep the utility “whole” with respect to collecting revenues to cover its fixed costs.

Thus, it would appear that community solar for low-income households could thrive because it benefits the business model of the incumbent energy stakeholders – the electric utilities. At the same time, as community solar models get adopted widely, there is a potential for “community washing.” It is unclear if the positive consequences of community solar will be experienced by participating communities, or if benefits will dis-proportionately be enjoyed by utilities or solar developers (Ptak et al., 2018). In addition, to foster the continued adoption of community solar, projects need to be financially beneficial for low-to-moderate income families (Vote Solar, 2018).

Despite the expanding penetration of low-income solar systems, research to date has not yet fully assessed what proportion of low-income housing is suitable for solar PV or what fraction of low-income electricity needs could be met by solar systems (Sigrin and Mooney, 2018). Such assessments need to consider the barriers that make it difficult for low-income households to acquire solar resources.

5.2 LEVERAGING THE HEALTHCARE BENEFITS OF ENERGY-EFFICIENT HOUSING

The healthcare industry has the potential to be a strong ally in the effort to reduce the energy burdens of low-income households. Problems associated with high energy burdens often include adverse health effects. Insufficient heating and cooling systems and leaky homes can cause hypothermia and heat stress. Improper air filtration, cracked heat exchangers, and poor ventilation can exacerbate asthma and other respiratory problems for occupants (Batterman et al., 2012; Doll, Davison, and Painting, 2016). Air conditioning units can transmit bacteria and lead to increased infection rates. Additionally, medical conditions often require electricity for treatment and medicines, such as diabetics needing refrigeration for insulin and those with breathing-related complications needing electrically powered breathing assistance devices. If updates to infrastructure are too costly and energy burdens are too high, households can end up sacrificing their health in order to cope with their energy bills. This in turn can lead to higher healthcare costs that further exacerbate the expenditure burden of households and lead to chronic stress (Hernandez et al., 2016).

The physical and mental health benefits of energy-efficiency upgrades are well documented (Camprubi et al., 2016; Fabian et al., 2012, 2014; Frey et al., 2015; Leventis et al., 2017; Coombs et al., 2018; Tonn et al., 2018). Surveys and case studies of residents systematically

identify favorable health effects (Hernandez and Philips, 2015; Hernandez et al., 2016). Based on the self-reports of public housing residents, Jacobs et al. (2015) found that green and healthy housing produced health benefits; specifically, there were reduced rates of hay fever, asthma, headaches, sinusitis, respiratory allergies, and angina. The latest WAP evaluation indicates that the value of the program's health benefits are significant (Tonn et al., 2018).

Collaboration and co-funding across the energy and healthcare industries offer an opportunity for both industries – and the vulnerable populations they serve – to benefit. The healthcare industry, and in particular Medicaid and Medicare and those states with value-based healthcare, have a vested interest in supporting healthy homes for low-income households that reduce medical costs. The energy industry often cannot invest in energy-efficiency measures or install rooftop solar systems without first making structural and safety investments (Breysse et al., 2011). Co-funded programs can leverage the potential benefits to both sectors (Kravatz et al., 2018; Ulrich et al., 2018). By combining health and safety housing improvements with efficiency retrofits using established energy-efficiency programs, the cost-effectiveness of efficiency investments can be strengthened. Spillman et al. (2016) provides examples of state initiatives where Medicaid funding has been used to make improvements, some of which are also energy-efficiency measures, and to educate residents about the health benefits of home energy upgrades. Healthy home measures include cleaning air conditioners and vents, improving HVAC systems, installing standalone air filters, plugging air leaks, and better insulation. By expanding the labor force of energy retrofit and public health professionals serving vulnerable populations, both stakeholder industries can improve (Dryden, et al., 2018).

5.3 BEHAVIORAL ECONOMICS AND SOCIAL SCIENCE APPROACHES

The study of low-income energy burdens is beginning to benefit from the emergence of behavioral economics and social-psychological approaches to understanding energy behavior.

Behavioral economics is the application of lessons from psychological and experimental studies to “nudge” people to change their behaviour. Well established concepts in behavioral and experimental economics on principal-agent problems, information asymmetry, and bounded rationality inform this research (Allcott and Rogers, 2014; Brown, 2001; Simon, 1976). However, most of these analyses do not focus specifically on low-income households. As a result, there is deep uncertainty about likely responses to information feedback, incentives, and an array of other policy interventions, and program offerings. Extant studies analyze the role of behavioral economics in determining and nudging people’s energy choices (Allcott and Taubinsky, 2015; Chetty, 2015; Sunstein and Reisch, 2014). Behavioral motivations may include monetary gains, information campaigns, education programs, audits and energy reports (Drehobl, Chikumbo, and Tanabe, 2018). The studies span a range of themes – behavioral response to energy efficiency, using green vs grey energy, willingness to pay, and community-based programs (Allcott and Taubinsky, 2015; Chetty, 2015; Sunstein and Reisch, 2014). As noted earlier, the incongruence between households’ values and intrinsic and extrinsic factors can limit their ability to adopt energy saving activities. This gap is especially relevant for low-income households, which generally have lower energy literacy than other income groups.⁶⁶

⁶⁶ <https://nef1.org/wp-content/uploads/2018/11/NEF-National-Energy-Literacy-Survey-White-Paper-181115.pdf>

Local governments are introducing programs that encourage behavior change at the consumer level. Several strategies have been adopted to engage residents and low-income households in energy-efficient behavior, chief among them being in-person engagement and education campaigns (Drehobl et al., 2018; Simms and Casentini, 2018; Craig, 2016). Most low-income adults are interested in learning about ways they can save on their electric or heating bills, and this is especially true among women and homeowners (Treadway, 2018). Further, awareness of utility energy-efficiency programs makes consumers more likely to participate in them (Craig, 2016). This finding was based on a large survey of 2,450 residential consumers, which enabled differences across income groups to be examined. The importance of program awareness as a predictor of program participation was found to be significant across all income groups, including households in the lowest cohort with incomes less than \$20,000. According to the opinion survey conducted by Treadway (2018), more than 80% of the respondents are interested in learning about ways to save on energy bills and low-income households are concerned about paying late fees and reconnection charges. Further, women, homeowners, and higher income households are more likely to be interested in these programs.

Some studies indicate there may also be high non-monetary costs associated with participation in a weatherization program that affect participation (Fowlie et al., 2015; Hirshfield and Iyer, 2012). Lack of knowledge about the features of different appliances and ineffective targeting can also lead to low uptake of these high-efficiency technologies among low-income households (O'Dwyer, 2013). Effective approaches to address different groups and sub-segments are going to be quite distinct (Treadway, 2018). Low-income program services and outreach messaging need to reflect the critical difference between sub-segments of vulnerable populations in the low-income market, including, for example, single mothers working two jobs, fixed-income senior citizens, and Native American populations returning to reservations (Treadway, 2018).

The limitations notwithstanding, local, municipal, and community level initiatives are likely to have greater success as they are closer to their target communities. Consistent with the findings on multifamily rental markets and rural customers, local engagement programs and partnering with local community-based organizations has significant gains and benefits (Hirshfield and Iyer, 2012; Simms and Casentini, 2018). This is also true in the case of household level usage of gas (Long et al., 2018). Niederberger (2018) suggests using “nudges” to encourage low-income energy consumers to buy energy-efficient products. These nudges would especially be effective in cases where the cost of more efficient products is comparable to their inefficient counterparts, because liquidity and budget constraints could otherwise prevent the purchase of more costly options. Further, designing a marketing model of local programs that take into account the role of behavioral changes by continued engagement, paying attention to customer experience, relying on strong stakeholder communication, and using interactions that allow for actionable information to be exchanged are all useful lessons for future program implementation (Keilty, 2018). Donovan, Bleything, and Enterline (2014) also note the potential for increasing energy efficiency by integrating technology that provides information on energy usage to low-income households. Advanced metering, in home displays, energy efficiency coaching, and providing usage information have all been successful strategies (Donovan et al., 2014).

5.4 DATA ANALYTICS

Finding: New publicly available data and tools on low-income energy consumption, are expanding. Nevertheless, more needs to be done to use these at a high spatial and temporal resolution to fine-tune program targeting and design.

New approaches have allowed for visibility into energy affordability and the socio-demographics of households. Data analytics and new digital tools such as the NREL Solar for All⁶⁷, and NREL ResStock⁶⁸ can help explain the relationship between energy affordability and socio-economic indicators to better understand the key factors that would drive changes in energy consumption. These techniques can be instrumental in estimating patterns of consumption and identifying areas where most of the savings can be made at the household levels (Hosgoer and Fischbeck, 2015; Long et al., 2018; Nahmens, Joukar, and Cantrell, 2015; Porse et al., 2016; Reina and Kontokosta, 2017; Wierzba et al., 2011; Zhang et al., 2018).

Jafary and Shephard (2018) use data from appliance usage to characterize consumption patterns of households across different building types. More high-quality data and techniques for analysis can also be useful in estimating the effect of the changing nature and composition of energy consumers. For example, Johnson et al (2017) use data from the PJM (a regional transmission organization) markets to estimate the effect of high solar PV adoption on cross-rate class subsidization and distribution of energy burden. Further, collecting and providing data can facilitate innovative approaches to analysis. It can help estimate the level and severity of the problem (Berry et al., 2018); it can be used to test the effectiveness of different low-income programs and project designs (Hoffman, 2017); to develop databases that predict deployment of new technology such as solar panels (Yu et al., 2018; Gupta et al., 2018b); further, data can be useful to draw more concrete results for utilities in order to target consumers who would gain from programs such as LIHEAP (O'Dwyer, 2017).

Understanding the impacts of low-income energy programs and policies can also be enhanced with data analytics. For example, the Greenlink Group has used mapping sciences to help visualize the relationship between household energy burdens at the county level and utility evictions in the State of Virginia (Figure 5.1).

Integrating new technology for collecting, generating and analyzing data can contribute to improved data analytics (Donovan et al., 2014; O'Dwyer, 2017). Machine learning techniques (Zhang et al., 2018) and agent-based modeling (Zhang et al., 2016) are promising approaches. With high-resolution data, investments in demand-side management can be designed to potentially displace the more expensive options of generation and grid investments (Reames, 2016; Khan and Duffy, 2018). All income groups would benefit from a shift from supply- to demand-side energy utility company investments enabled by data analytics. However, in many regions, such data are not available. The first step in making better data analytics possible will therefore be collecting, analyzing, and visualizing more spatially and temporally high-resolution data to better inform low-income energy programs (Reames, 2016).

⁶⁷ <https://maps.nrel.gov/solar-for-all/?aL=6m-d90%255Bv%255D%3Dt&bL=clight&cE=0&lR=0&mC=38.870832155646326%2C-98.34521484375001&tour=splash&zL=5>

⁶⁸ <https://www.osti.gov/biblio/1436972>

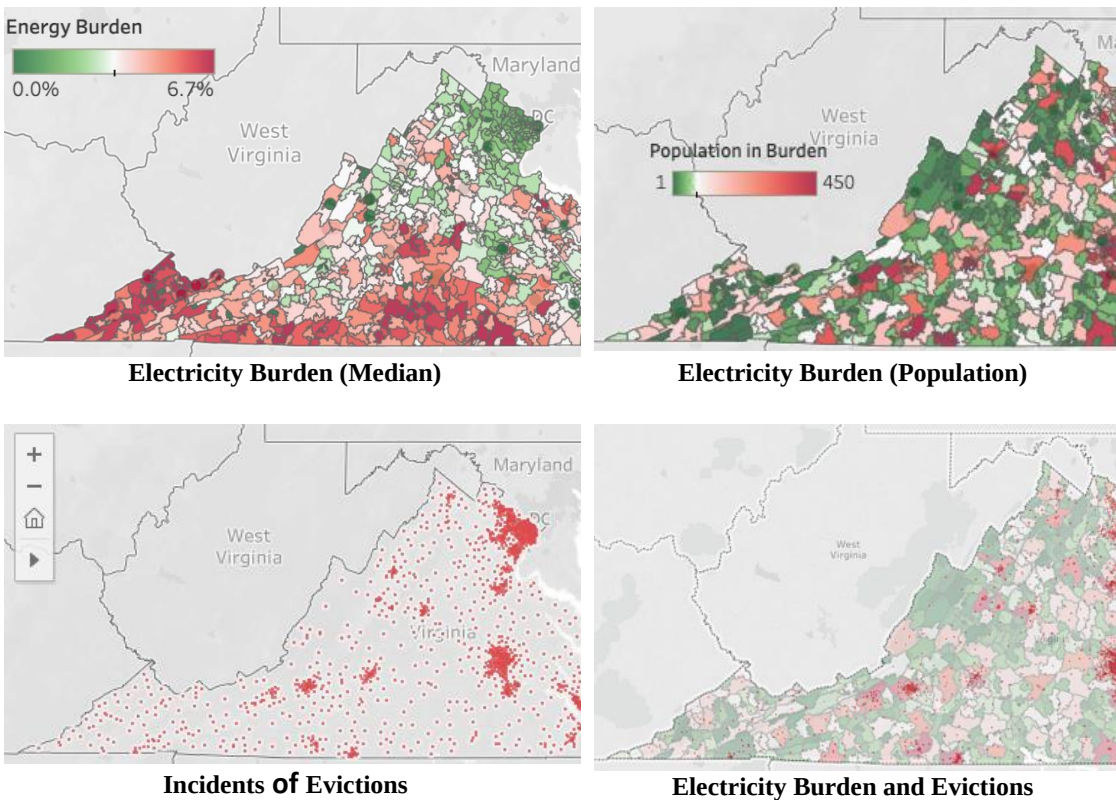


Figure 5.1 Data analytics of energy burden and evictions across zip codes in Virginia⁶⁹

5.5 ADVANCED INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)

Finding: Information and communication technologies including smart thermostats and information feedback support low-cost behavioral approaches to improving energy efficiency, but they tend not to be incorporated into low-income energy programs.

Digital, market-based programs are being used to educate, incentivize, and “nudge” consumers to purchase energy-efficient products (Niederberger, 2018). Adopting behavioral strategies supported by technology and data to target online marketing for greatest impact can scale participation and improve the cost-effectiveness of residential programs to reduce energy burdens. Digital platforms and smart meter data are being deployed to reach households with high energy burdens (Sovacool et al., 2017). Energy burdens could be reduced if low-income tenants had a more expansive knowledge of how best to conserve energy, and ICT can help achieve this greater energy literacy. However, low-income households often lack Internet access – a “digital divide” exists. At best, they are unable to use such platforms or at worst, could be harmed by such business models.

When low-income respondents were asked how they would like to receive daily account information from their local utility, e-mailing was the dominant response, representing 45% of the households. Text messaging was viewed as the preferred information mechanism by 15%,

⁶⁹ <https://www.thegreenlinkgroup.com/energy-equity>

and the use of a mobile app by 12% of respondents (Table 5.1). Consistent with the digital divide, elderly and lower-income households are less likely to prefer the use of mobile apps (Treadway, 2018).

Table 5.1. Favorite way to receive daily account information from local electric utility
(Source of data: Treadway, 2018)

	Age		Household Income		
	Total	18-54	55+	< \$25K	\$25K to \$49
Total Respondents with HH Income Less than \$50,000	(534)	(364)	(170)	(232)	(302)
	%	%	%	%	%
Email	45	42	53*	41	48*
Text message	15	16	12	19*	12
Mobile app notification	12	15*	4	8	15*
More than one channel (phone, text message, email or app)	10	11	10	10	11
Recorded phone call	4	4	5	6*	3
Don't know/no opinion	13	12	17	16	12

Q. B18: If you elected to receive daily account from your local electric utility, how would you receive it? Please choose your top choice. *Indicates figure is significantly higher than other sub-group at a 95% confidence level. The Russell Omnibus was conducted via the Internet among 1,092 adults 18 years of age or older from October 21-24, 2016.

One way for households to easily access and recognize their energy consumption is through the use of smart meters and smart thermostats. Smart meters enable a wireless two-way communication with the utility company (Brown, Zhou, and Ahmadi, 2018). These smart meters allow the utility companies to track peak demand times and usage. Nest thermostats are WiFi enabled and can be controlled by computers and cell phones. They display the current energy consumption of the home and have sensors for temperature, humidity, and motion. The Nest thermostat learns the user's behavior, guarantees that no energy is wasted if no one is home, and helps manage usage during peak and off-peak times to help low-income households lower their total energy bill. Nest thermostats can be expensive at \$250 before installation, deterring many low-income households from purchasing the device. Georgia Power currently offers a \$100 rebate on Nest thermostats, but for low-income households, \$150 is still a large sum of their monthly income. Therefore, implementing a monthly payment plan, on top of the rebates as an incentive program, is more feasible for these families. A Nest thermostat, on average, saves a household \$140 per year, hence the price per month that they will pay for the Nest thermostat would be equivalent to the monthly savings made through their electric bill.⁷⁰

“Peer-to-peer electricity” sharing could create a more affordable marketplace for electricity. In this marketplace, the people who can afford power generating sources such as solar panels can

⁷⁰ Nest Thermostat Real Savings. (n.d.). Retrieved April 22, 2018, from <https://nest.com/thermostats/real-savings/>

sell electricity to people who are unable to afford generating sources or who might have access to electricity but require more electricity at certain times (Inam et al., 2015). While this concept appears to not be operational in the U.S., it is beginning to enter markets in the Netherlands and Australia.⁷¹

5.6 GRID RESILIENCY

Electric and natural gas service disruptions due to extreme weather events and other hazards have brought increasing attention to, and study of, the resiliency benefits of energy system resources. In that vein, study of low-income energy efficiency and renewable programs, community-level microgrid infrastructure projects, and programs that may facilitate these local energy programs is an emerging area of study. While the definition of how-to value “resiliency” varies depending on program perspective and evaluation context, generally speaking, resiliency concepts refer to the flexibility of energy system resource(s), and the ability to “bounce back” and recover from system disruptions (natural and otherwise), as well as to adapt and improve over time.

Ribeiro et al. (2015) suggest that value and risks relating to resilience can be understood in terms of hazards, vulnerability, and capacity to cope.

Risk = Hazards x Vulnerability

Capacity to cope

Green Mountain Power has initiated a bold experiment to turn a low-income community into a virtual power plant. It is currently implementing the first community rooftop solar arrays for local low-income households in conjunction with battery storage that are helping customers move off the central grid for several hours every day.⁷²

As utilities become more targeted in deploying energy efficiency to strengthen grid reliability by considering the time-varying and locational value of demand management, there is an opportunity to address challenges of economically distressed communities at the same time. This was achieved in a “non-wires alternatives” pilot program located in an economically depressed area, offering a learning experience for program design and implementation under such circumstances. Energy analytics played an important role in assessing the demand side management potential in the target area and to drive targeted and personalized customer interactions during implementation (Khan and Duffy, 2018).

⁷¹ <https://vandebron.nl/about>; <https://arena.gov.au/assets/2017/10/Final-Report-MHC-AGL-IBM-P2P-DLT.pdf>

⁷² New York Times, Utility helps wean Vermonters from the electric grid,
<https://www.nytimes.com/2017/07/29/business/energy-environment/vermont-green-mountain-power-grid.html>

6. CONCLUSIONS

In the midst of a rapidly transforming energy system, this paper reviews the literature to assess how low-income energy burdens are changing, what policies and programs are impacting them, and what opportunities hold promise for progress in the future. Our literature review uses an energy equity lens to focus on procedural, distributional, and intergenerational issues related to low-income energy burdens.

Our literature review is complicated by several methodological challenges:

- Variable and inconsistent definitions and metrics are used to describe the energy consumption patterns of low-income households.
- The extent and nature of energy burden, and the estimated impact and value of solutions, depend upon the metrics used.
- There is limited publicly available data on low-income energy consumption, particularly at high spatial and temporal resolution, which constrains the ability of data analytics to fine-tune program targeting and design by federal, state, and local agencies, communities and NGOs, and utility companies.

The last decade has produced a large and expanding literature on low-income energy burden. Several broad conclusions are derived from that literature, which have equity implications.

- Energy burden is higher among low-income households than other income groups.
- The average energy burden of low-income households is not declining, and it continues to be high in particular geographies and socio-economic groups.
- Many policies and programs that promote energy efficiency and renewable energy technologies (e.g., rooftop solar PV and home battery systems) are largely inaccessible to low-income households, although several states have recently launched major low-income solar programs.
- The share of utility residential energy-efficiency funding that supports low-income households is lower than the percent of residential utility customers who are low-income.

The literature also documents a number of new approaches to the design and implementation of low-income energy programs and policies that appear to offer opportunities to amplify their success.

6.1 IMPROVING ENERGY EQUITY THROUGH PROGRAM DESIGN AND IMPLEMENTATION

A majority of low-income energy program funding focuses on short-term fixes to energy insecurity and not long-term solutions to reduce energy burden.

- Funding for temporary assistance (e.g., for bill payments) dwarfs funding for more enduring assistance (e.g., weatherization), though both serve a critical need and benefit from being linked.
- Funding for low-income energy programs peaked as a result of ARRA; it has returned to levels above the pre-ARRA funding, reflecting modest increases in weatherization funding and more substantial increases in low-income solar programs.

A number of submarkets and socio-demographic groups tend to be underserved by current low-income energy programs. Programs like WAP serve both to reduce energy burden and to improve the low-income housing stock across the country by making it more energy-efficient, comfortable, and healthier. Because many low-income energy programs serve homeowners, they also mainly serve white households (a distributive justice concern). Eliminating barriers to serving rental properties could drastically reduce energy burden and insecurity for households of color while reducing health and other racial disparities. This would benefit from additional research on the nature and role of landlords and property owners, which was found to be a notable gap in our review of stakeholders covered in the literature.

- The multifamily low-income market has been difficult to reach with traditional energy-efficiency programs due partly to misalignment of incentives.
- The opportunity to address the high energy burden of low-income households occupying manufactured and mobile homes has received limited analysis and policy focus.
- Low-income households in rural communities often spend as much as a quarter of their income on energy due partly to their low-density geography; assistance from local community programs and organizations are particularly critical to success in these markets.

Several promising technology approaches are not generally well integrated into low-income energy programs.

- Rooftop and community solar systems are now cost effective in many states as the result of declining costs and their involvement in low-income energy programs is beginning to take hold in some states.
- Health and safety upgrades are not components of most utility low-income energy-efficiency programs, and they are not fully integrated into the cost-benefit calculations of the WAP or state low-income energy programs.
- Information and communication technologies including smart thermostats and information feedback support low-cost behavioral approaches to improving energy efficiency; while they tend not to be incorporated into low-income energy programs, their presence in these programs is increasing.
- Electric vehicles and other approaches to affordable transportation have played limited roles in federal, state, local, and utility low-income energy programs to date.

Policies can be designed to address these gaps.

- States are using minimum requirements and adders to cost-effectiveness tests to promote greater investment in low-income energy programs.
- New program designs can align incentives more effectively for building owners and tenants.
- Strong community engagement and effective building owner and property manager partnerships can help reach multifamily markets.
- Active community involvement can expand participation rates and enhance the success of low-income energy programs.

6.2 SCALING IMPACTS WITH LEVERAGING, PARTNERSHIPS, AND PROGRAM INTEGRATION

Scalable approaches to reduce low-income energy burden require linking programs and policies to tackle the complex web of causes and impacts that households face, who have limited resources to pay energy bills. Two distinct opportunities exist: inter-agency cooperation and integrated technology-policy approaches.

Inter-agency partnerships offer greater resources and leverage, particularly if they span multiple scales (national, regional, state, and community) and multiple agencies with missions that touch on low-income energy burden. Evidence of the potential payback to engagement of non-energy agencies is provided by the significant non-energy benefits that are created by low-income energy programs.

- At least four parallel federal programs have missions related to low-income energy burdens, with varying levels of inter-agency coordination at the federal, state, and local levels.
- The savings-to-investment ratio of WAP is favorable based on the value of its energy savings alone.
- Without monetizing non-energy benefits, low-income energy-efficiency programs operated by electric and gas utilities cost more to implement per household and are less cost-effective than utility-operated energy-efficiency programs serving higher income groups. Low-income energy programs ensure low-income households can benefit from ratepayer funding that they help pay for but would otherwise not benefit from.
- The value of the non-energy benefits of WAP and other low-income energy programs are significant.

Integrated technology-policy approaches offer opportunities to leverage a broader array of rapidly advancing technologies (advanced efficiency, solar PV, storage assets, smart meters, and more). Expanding implementation of these technologies can be achieved with novel and integrated approaches to inclusive financing, philanthropic partnerships, energy assistance, and payment arrangements. More holistic approaches can maximize benefits and minimize costs.

- Expanding the technology scope of low-income energy-efficiency programs to include solar PV, smart meters, storage, and electric vehicles could significantly improve energy affordability for low-income households.
- Broadening finance and administrative options (e.g., on-bill tariff designs) can maximize benefits and minimize costs, if designed effectively.
- Public-private-philanthropic-partnerships and interagency coordination and leveraging can reduce energy costs for low-income households while also delivering non-energy benefits.

Both funding and execution will require finely meshed and interwoven delivery systems that engage all the stakeholders shown in Figure 1.1. A coordinated approach to home energy, health, safety, and housing that integrates programs across geographies could reduce low-income energy burden while delivering numerous other benefits to both current and future generations. As the U.S. transitions to a new energy economy, these solutions offer low-income households the opportunity to meet their energy service requirements more affordably.

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STATE OF MICHIGAN

BEFORE THE MICHIGAN PUBLIC SERVICE COMMISSION

In the matter of the application of **DTE
ELECTRIC COMPANY** for authority to
increase its rates, amend its rate schedules
and rules governing the distribution and
supply of electric energy, and for
miscellaneous accounting authority

Case No. U-21534

ALJ Sally Wallace

PROOF OF SERVICE

I, Mark N. Templeton, certify that an electronic copy of the Accompanying Exhibits DAO-118 to DAO-124 (Part 3 of 5) for the Direct Testimony of Justin Schott on Behalf of Soulardarity and We Want Green, Too was served on the following on July 26, 2024.

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The statements above are true to the best of my knowledge, information, and belief.

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