Energy Burdened Households in the United States: Towards policy implications for three major U.S. Cities

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ABSTRACT

Recently, cities have become more focused on housing affordability, displacement, and other equity topics, as these issues create disparate outcomes within closely located communities. Residential energy burden is similarly emerging as a major equity issue. An energy burdened household is one in which residents pay a significant proportion of their income to utilities. Households struggling with high energy burdens may experience economic disadvantages, health risks, and increased mental stress. A majority of highly burdened households are low-income, people of color, renters, and have difficulty breaking out of a cycle of burden (Drehobl and Ross 2016).

Progress toward more sustainable and equitable community outcomes can be made when energy burden is addressed strategically with energy efficiency. The underlying conditions of energy inequity should be understood so that informed, evidence-based policy approaches can be pursued and implemented. Although income is a determinant of high energy burdens, poor housing stock conditions, low-performance equipment, utility rate structures, and few resources for utility bill assistance may also contribute significantly to disproportionate energy costs. All of these issues are manifestations of systemic racial and social biases in the U.S.

Using a fixed effects model to isolate the effects of dynamic societal conditions, this research examines the drivers of utility burdens in three U.S. cities at a neighborhood scale. Energy burden reduction opportunities are forecasted through an evaluation of potential energy efficiency technologies using several utility cost tests. A discussion around leveraging current and future energy policies to redress systemic inequities in the residential energy ecosystem concludes.

Overview of Energy Burden

Energy provided by a utility is a necessity for nearly all urban households within the United States, however a large proportion of households are unable to afford it. In 2015, nearly one-third of low-income households reported household energy insecurity, while over 20% reduced their consumption of basic necessities to pay their energy bills (EIA 2018). The term 'energy burden' represents a percentage of annual income a household spends on their electricity and natural gas bills (Drehobl and Ross 2016; Gavryliuk 2018). The percentage threshold indicating a severe energy burden is heavily debated; some scholars point out that a household is "energy poor" when 6% of their income is used to power their homes (Colton 2011), while others conclude a household is burdened at a threshold of 10 or 11% (Fisher, Sheehan, and Colton 2013; Hernandez and Bird 2010). Regardless of the definition used, households faced with high energy burdens can suffer from negative health consequences as they may have to choose between maintaining a clean, comfortable indoor environment and reducing their electricity expenditure (Gavryliuk 2018; Brown 2019). A survey of Americans receiving federal assistance concluded that "19 percent [of low-income households] became sick because their home was too cold" (Choate and Wolfe 2011). Children, elderly and disabled individuals have an increased risk of poor health outcomes, especially those experiencing low-incomes or living in older housing stock.

Three leading variables are involved in determining a household's electricity burden: the quantity of electricity consumed, the price of electricity, and household income (Teller-Elsberg 2016). Energy burden is a function of income, so it is not coincidental that low-income households make up the majority of households that experience high energy burdens, however, other variables have been determined. Recent research correlates demographic factors, housing tenure and geographic characteristics with high energy burden (Berry, Hronis, & Woodward 2018, Drehobl & Ross 2016, Hernandez & Bird 2010, Porse & Derenski 2016, Ross, Drehobl, & Stickles 2018). Households that experience high energy burdens often include renters living in homes that contain minimal or outdated insulation and/or appliances. African Americans and Latino communities face disproportionally high utility bills and African Americans find it more difficult to obtain and maintain wealth than their white counterparts, resulting in higher rental housing rates (Drehobl and Ross 2016; Rothstein 2017). To improve equity outcomes, it may be imperative to focus bill assistance and utility demand-side management (DSM) programs towards low-income households, renters, and/or African American and Latino communities.

Energy efficiency improvements can lead to increased comfort and productivity and decreased utility spending from the resident. In Connecticut, a light touch retrofit (sealing air ducts, replacing incandescent lightbulbs with LED lightbulbs, etc.) to an average home resulted in an 18.5% rate of return on investment (Nadel 2019). Unfortunately, incentives for energy efficiency and home retrofitting are most-frequently provided to homeowners in single family dwellings, making it more difficult for low-income renters to benefit from efficiency programs and shrink high energy costs. Low-income households are often more difficult to reach or require more expansive upgrades; the cost of saved energy through efficiency programs is nearly 6 times as much as the average household (Schwartz and Hoffman 2019). Effective residential efficiency programs offered by utilities often have high upfront costs, making them ineffective and often inaccessible for renters or low-income households (Cluett, Amann, and Ou 2016; Drehobl and Ross 2016). Programs designed to help low-income households through bill assistance can provide temporary relief temporarily relieve some of the high cost of energy, however many of but these solutions are not long-term solutions. In 2011 alone, the United States Department of Housing and Urban Development (HUD) spent $7.1 billion on utility bill assistance (U.S. Department of Housing and Urban Development). Progress toward more sustainable and equitable outcomes can be made when energy burden is addressed strategically with energy efficiency, bill assistance, and sufficient resources. The underlying conditions of energy inequities should be understood, so that informed, evidence-based policy approaches can be pursued and implemented. A quantitative study of these issues can assist in uncovering these conditions as a part of a comprehensive engagement strategy that includes community empowerment and a drive towards consensus in developing strategies that best incorporate local context in producing better outcomes.

The Role of Energy Efficiency and Benefit-Cost Tests on the Issue of Burden

Benefits of energy efficiency include, but are not limited to, decreased utility bills to residents and business owners, enhanced grid performance, lower operating costs, and improved health and environmental outcomes (Lazar 2013). Often, energy efficiency is an underutilized resource from utilities in their planning processes (EPA 2008).

The value utilities place on energy efficiency measures varies depending on what is considered cost-effective. Only half of the energy efficiency potential is likely to be achieved in the next twenty years due to structural and market barriers that have gone unresolved (Hirst and Brown 1990; Nadel and Ungar 2019). Five benefit-cost tests established decades ago are the standards used in efficiency program evaluations to consider benefits and costs from various perspectives. Utilities most often refer to the total resource cost test (TRC), followed by the societal cost test and the utility cost test (SCT and UCT, respectively) as primary approaches to evaluating their efficiency programs (ACEEE 2020).[1] While the widely-used TRC includes benefits such as reduced capacity and generation costs for the utility, it does not consider non-monetized benefits to the customer such as increased comfort or improved health. Furthermore, the decision to implement an energy efficiency program frequently devolves to relying on a binary result of ‘pass/fail’ over a territory, stripping out distributional considerations in program design.

We dissect the use of cost tests within utility resource planning contexts and the effects on household energy burden, particularly within low-income communities in Atlanta, Los Angeles and Denver. Electricity burdens and some of its drivers are then evaluated. Energy efficiency scenarios are then applied to the top three burdened census tracts using the pass/fail cost-test method in order to understand the potential of utility efficiency programs on highly burdened households.

Calculating Energy Burden

Energy burden is the proportion of annual household income dedicated to paying energy bills. To calculate energy burdens on a census tract level within each city, annual household income and household electricity and gas bills data were collected. Annual surveys collected by American residents regarding several economic, geographic and household indicators, including utility spending and household income were collected by the Census Bureau through the American Community Survey (ACS). About 11,000 survey responses from 2013-2016 across Atlanta, Los Angeles and Denver are included in our analysis and were treated prior to the inclusion to account for incomplete responses. Los Angeles experiences a population roughly 2 times the population of Atlanta (Fulton and Dekalb County) and 6 times the population of Denver, rendering a higher survey response rate.

To determine the average annual utility bill for a census tract, Public Use Microdata Area (PUMA) level utility spending data is synchronized with census tract income data through a weighted average calibration. This process of synchronizing PUMA data with census tract data assumes that census tracts experience median utility bills similar to those from surveyed households with the median income of that PUMA region; incomes are disaggregated into 62 brackets, used to further inform and calibrate the utility bill and burden analysis. By assigning each PUMA and ACS response with one of the 62 income brackets allows regions to be compared with one another. This assumption recognizes the spatial disparity between PUMA groups and census tracts; income brackets within a PUMA region are most likely to be aligned with and are by definition composed of matching income census tracts within that region. Utility

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[1] A full breakdown of each cost-test is provided by the Midwest Energy Efficiency Alliance (MEEA). California primarily uses the TRC and utility cost tests to evaluate cost and benefits of energy efficiency programs, Colorado and Georgia use the TRC (ACEEE 2020).

burdens are then calculated by dividing the calibrated utility spending by block group median household income given by ACS.

The survey data were combined with Princeton University's Eviction Lab data and the Center for Disease Control's (CDC) chronic disease risk factors to produce a database providing annual burden data by census tract along with a number of potential socio-economic and health-related indicators (ACS 2017). To determine any potential linear correlations, a Pearson correlation coefficient was calculated between each burden and indicator (Table 1c). A value of ± 1 represents a total positive or negative linear correlation, while values closer to 0 can be interpreted as no linear correlation. Values between ± 0.50 and ± 1 are considered to have a high degree of linear correlation.

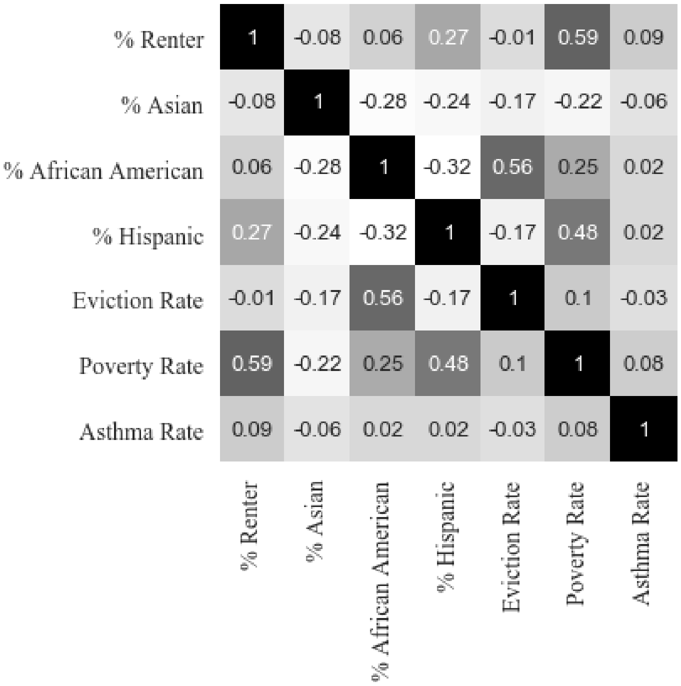
Table 1a. Summary statistics for the dataset spanning three cities: Atlanta, Los Angeles, and Denver

Indicator	Number of Records	Average	Std. Dev.
Renter-Occupied Housing	11,175	52.4%	0.259
Population: Asian	11,211	12.2%	0.148
Population: African-American	11,211	13.0%	0.220
Population: Hispanic	11,211	41.9%	0.304
Median Energy Burden	10,995	6.4%	2.142
Multi-Family Housing	11,178	39.3%	0.299
Eviction Rate	11,220	1.7%	0.032
Poverty Rate	11,220	15.4%	0.127
Asthma Rate	11,220	1.6%	0.034

Table 1b. Summary statistics for each city

	Atlanta			Los Angeles			Denver		
Indicator	Number of Records	Average	Std. Dev.	Number of Records	Average	Std. Dev.	Number of Records	Average	Std. Dev.
Renter-Occupied Housing	1,379	48.6%	0.24	9,228	53.1%	0.26	568	48.9%	0.22
Asian	1,387	5.2%	0.08	9,256	13.8%	0.16	568	3.3%	0.03
African-American	1,387	48.3%	0.37	9,256	7.9%	0.13	568	8.7%	0.10
Hispanic	1,387	8.1%	0.12	9,256	47.7%	0.29	568	29.1%	0.24
Median Energy Burden	1,372	6.3%	0.04	9,085	6.6%	2.36	538	3.9%	0.03
Multi-Family Housing	1,382	41.1%	0.29	9,228	38.9%	0.30	568	40.5%	0.29
Eviction Rate	1,388	5.3%	0.06	9,264	1.1%	0.02	568	2.2%	0.02
Poverty Rate	1,388	16.4%	0.15	9,264	15.4%	0.13	568	13.1%	0.12
Asthma Rate	1,388	1.3%	0.03	9,264	1.6%	0.03	568	2.2%	0.04

Table 1c. Pairwise correlation table for each indicator in the dataset spanning three cities: Atlanta, Los Angeles, and Denver.



	% Renter	% Asian	% African American	% Hispanic	Eviction Rate	Poverty Rate	Asthma Rate
% Renter	1	-0.08	0.06	0.27	-0.01	0.59	0.09
% Asian	-0.08	1	-0.28	-0.24	-0.17	-0.22	-0.06
% African American	0.06	-0.28	1	-0.32	0.56	0.25	0.02
% Hispanic	0.27	-0.24	-0.32	1	-0.17	0.48	0.02
Eviction Rate	-0.01	-0.17	0.56	-0.17	1	0.1	-0.03
Poverty Rate	0.59	-0.22	0.25	0.48	0.1	1	0.08
Asthma Rate	0.09	-0.06	0.02	0.02	-0.03	0.08	1

To investigate key determinants of energy burden, a state-of-the-art fixed effects model is developed for each of the three geographies included in this study. A fixed effects model is justified through a Hausman test and the fact that our key explanatory variables are time-varying. A benefit of this model is that it allows us to estimate “all else equal” conditions over time, therefore isolating the effects of each indicator, making it a more convincing tool for policy and socio-economic analysis (Wooldridge 2009). The model generally takes the form:

(Eq. 1)

$$Burden = \alpha + Asian + AfricanAmerican + Hispanic + u$$

Where:

Burden is the median energy burden

Asian/African American/Hispanic is the proportion of the population identifying with a particular race/ethnicity

To control for changes in median income, a second model is run to include all variables above as well as the log of income (***linc***). A final equation (equation 2 in the table below) shows the results of a model run with the equation:

(Eq. 2)

$$\mathit{Burden} = \alpha + \mathit{Renter} + \mathit{Asian} + \mathit{AfricanAmerican} + \mathit{Hispanic} + \mathit{MFH} + \mathit{Eviction} + \mathit{Poverty} + \mathit{Asthma} + \mathit{linc} + u$$

Where:

MFH is the proportion of the population residing in multifamily housing
Eviction is the eviction rate per 100 renter households
Poverty is the proportion of the population living below the Federal Poverty Line
Asthma is the prevalence of asthma in populations 18 and older
Renter is the proportion of the population that rents housing
linc is the log of median-income for each census tract

This model is consistent with the recent literature and hypotheses about socio-economic determinants of energy burden, especially in urban contexts (Li 2019). In order to explore the importance of income, a second model is presented (Equation 2) whereby ***Renter, MFH, Poverty and Asthma*** are dropped, and the log of median income is used as a replacement. Calibrating the model with both income and energy bills raised concerns of overfitting, however the results were consistent with other recent research (Lyubich 2020).

(Eq. 2)

$$\mathit{Burden} = \alpha + \mathit{Asian} + \mathit{AfricanAmerican} + \mathit{Hispanic} + \mathit{Eviction} + \mathit{Log\ Income} + u$$

Utility Cost Tests

We conduct all five cost-tests for Los Angeles, Denver and Atlanta. These cities were chosen for their differences in utility structure, political context, and climate. Colorado Public Service Company (Denver) and Georgia Power Company (Atlanta) are vertically-integrated investor owned utilities (IOUs), while Los Angeles Department of Water and Power is municipally-owned. A key source of information on efficiency technology options is a utility's technical reference manual (TRM), which documents energy efficiency measure impacts for a utility's energy efficiency portfolio (Schiller, Leventis, and Eckman 2017). TRMs were not available for all utilities, so energy efficiency potentials as a percent of sales were taken from the Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL).[2] For consistency, measures recommended by NREL using the ResStock Analysis Tool were used to evaluate the cost-tests for each city (NREL 2019).

Ten cost-effective energy efficient technologies for California, Colorado, and Georgia were chosen (Table 2) (NREL 2019).[3] The ResStock results provide annual bill savings, which was then used to calculate kWh savings using blended residential rates for each utility (EIA 2018). To calculate the lifetime costs and benefits associated with each efficiency technology, measure lifetimes for each recommendation were taken through NREL's National Residential Efficiency Measures database. The lifetimes for each technology were used to calculate the energy-related and capacity benefits to the electric power system. Incremental program-related and incentive costs for each technology were gathered by utility (EIA 861). Energy and capacity benefits are estimated for each utility by using sub-regional EIA data (EIA 2020). Lastly, present

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[2] The DOE reports 18.3%, 13.7% and 14.4% energy efficiency potentials for Georgia, Colorado and California, respectively. NREL determines savings of 26%, 19% and 17% for those same states.

[3] Top ten technologies selected for this analysis can be found for each state through the NREL summary of the cost-effective residential savings potential. summary of the cost-effective residential savings potential.

value cost streams are calculated using an 8.5% discount rate to approximate a weighted average cost of capital.

All technologies that did not pass the respective cost-tests were dropped from the analysis. This approach shows the potential average impact should the utility context use any particular test to evaluate energy efficiency opportunities. To derive energy savings from passing technologies, electricity consumption was back-calculated from survey bill data and blended rates for the three highest burdened census tracts in each city. A weighted average kWh savings for each technology "family" (HVAC, Water Heater, Enclosure, and Lighting) was applied to each household's energy consumption and bills were recalculated. There were instances in certain multifamily homes where reported energy savings were greater than the original technology family consumption. In order to avoid an overestimation of savings, the resulting household's energy consumption was compared to predicted energy consumption for an average home within each city as reported by EIA's RECS data. Some appliances were more efficient than the original and thus provided zero or negative consumption. In this case it was assumed that energy saved did not exceed the original consumption.

Table 2. Top Ten Energy Efficiency Technologies for Each State

Improvement Measure	CA	CO	GA
Drill-and-fill wall cavity insulation	x	x	x
High-efficiency heat pump (replace electric furnace at wear out)	x	x	x
LED Lighting	x	x	x
Smart Thermostat	x	x	x
R-49 attic insulation	x	x	x
Duct sealing & insulating	x	x	x
Ductless heat pump (displaces electric baseboard)	x	x	
R-10 crawlspace walls	x	x	
R-10 basement wall insulation		x	
R-5 insulated wall sheathing (at siding replacement)		x	
Heat pump water heater (replace electric water heater at wear out)			x
High-efficiency heat pump (replace propane furnace at wear out)			x
SEER 16 central air conditioning	x		x
Low-E storm windows (DIY install)	x		x

Results

Table 3 shows the calculated average electricity burdens for all and each individual city in 2017. The overall average electricity burden across all three cities is 3.06%; 1.2 times higher than the national average (EIA 2016). This burden increases when you consider people of color and renters. For African-Americans, the average electricity burden in 2017 was 4.27% (1.7 times higher than the national average), and 3.56% for renters in multifamily housing (1.4 times higher than the national average). Across all cities, African-American households experience a burden that is nearly twice that of white households while showing lower bills and consumption levels on average. For example, African American electricity bills are $100 lower than their white counterparts in Atlanta. A similar story can be told for Hispanic households in Los Angeles. These results suggest higher household energy intensities and lower incomes may be primary determinants of energy burdens for these populations since average gross consumption is clearly not the cause. Asian households experience the lowest burden and bills compared to other races across all cities.

Table 3. Average Electricity Burdens and Electricity Bills

	Overall Population	Renters	Owners	White Population	African-American Population	Asian Population	Hispanic Population
Overall Burden	3.06%	3.56%	2.20%	2.67%	4.27%	2.01%	2.81%
Electricity Bill	$1,579	$1,364	$1,706	$1,640	$1,675	$1,442	$1,438
Atlanta	3.83%	4.36%	2.80%	2.57%	4.74%	1.46%	3.30%
Electricity Bill	$1,745	$1,348	$1,958	$1,744	$1,642	$1,227	$1,754
Los Angeles	3.03%	3.48%	2.15%	2.77%	4.05%	2.05%	2.80%
Electricity Bill	$1,591	$1,384	$1,703	$1,679	$1,711	$1,459	$1,441
Denver	1.61%	2.41%	1.49%	1.57%	3.56%	1.44%	2.84%
Electricity Bill	$918	$900	$1,148	$931	$1,298	$768	$1,141

Fixed Effects Model Results

Table 4 details the results of the fixed effects models for each city. Looking at race alone, equation 1 results show that race is extremely significant in Atlanta and Denver in determining energy burdens. A 1% increase in African American populations in Atlanta is correlated with an 8% increase in energy burden. Interestingly, modifying that model to include median income (not shown) shows the opposite correlation - holding income constant, we see that an increase in African American or Latino populations reduces energy burden. In Atlanta, these populations have lower energy bills than their white counterparts (Table 3), suggesting lower energy consumption than whiter communities with similar income characteristics.

Table 4. Model Results

	Atlanta (1)	**Atlanta (2)**	**Los Angeles (1)**	**Los Angeles (2)**	**Denver (1)**	**Denver (2)**
Asian	0.034***	-0.036***	-0.177	-2.235	0.073*	0.026
African American	**0.082*** **	**-0.023*** **	**-0.111**	**-3.641**	**0.024** **	**-0.009**
Hispanic	0.051***	-0.068***	-0.111	-2.905	0.036***	0.001
Eviction		**-0.039**		**3.517**		**-0.024**
Log Median Income		-0.145***		-11.903		-0.053***
Poverty		**0.093*** **		**-7.550**		**0.033**
Asthma		0.145		-1.813		0.251*
Multifamily		-0.004		0.022		-0.004
Renter		**-0.028** **		**-3.661**		**0.008**
Overall R2	0.33	0.64	0.000	0.20	0.148	0.32

*p<0.1, **p<0.05, ***p<0.01

Utility Efficiency Program Potentials

Table 5 summarizes the proportion of the cost-effective ResStock residential efficiency portfolio that survives each cost test. The top number shows the average energy burden savings obtained through each cost-test portfolio. Although it appears that Los Angeles shows a greater portion of identified energy savings surviving the TRC, their statewide energy potential (in parentheses next to the city name) is roughly 10 percent less than Atlanta's. The percentage of the ResStock portfolio that survives the cost test is shown in parentheses underneath the energy savings. Unsurprisingly, the TRC and Ratepayer Impact Measure (RIM) tests retain the least energy savings.

Table 5. Results of Cost-Tests in Comparison to State-Wide Efficiency Potentials

City (ResStock Potential)	TRC	PCT	SCT	PACT	RIM
Los Angeles (17%)	6.5% (38%)	10.7% (63%)	9.3% (54%)	6.6% (38%)	0% (0%)
Denver (19%)	1.8% (9%)	2.8% (15%)	2.2% (12%)	2.5% (13%)	0% (0%)
Atlanta (26%)	3.6% (14%)	7.3% (28%)	3.7% (14%)	6.6% (25%)	0% (0%)

Table 6 below shows the resulting median energy burden if the efficiency measures surviving a cost test were implemented in the median household in the three highest-burdened census tracts across each city. The 2017 average energy burden across the three highest-burdened tracts is shown in parentheses next to the city name in the first column for reference.

Table 6. Cost-Test Implications on Highest Burdened Census Tracts across Three Cities

State	TRC	PCT	SCT	PACT	RIM
Los Angeles (19.9%)	13.4%	9.2%	10.6%	10.1%	19.9%
Denver (5.5%)	3.7%	2.7%	3.1%	3.3%	5.5%
Atlanta (10.3%)	6.7%	3.0%	5.6%	6.6%	10.3%

Atlanta experiences the greatest reduction in energy burden across all cost-test efficiency scenarios besides the RIM test, due to its higher state-wide energy efficiency potential and large measure savings. Colorado experienced the smallest burden reduction, regardless of the fact that Colorado Public Service Company had the most extensive rebate program and cost-test results (Table 2). This is due to the higher installation costs associated with each measure and the baseline efficiency of many of Denver's homes.[4]

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[4] The average energy use intensity used for Denver's top burdened homes was 9.39 kWh per square feet. This is roughly 2.6 times less than California and 2.2 times less than Georgia's housing structures (DOE 2015).

Discussion

The impacts of these cost tests on the ability to achieve the energy policy goals are important to understand. Housing affordability and energy burden are widely recognized equity issues in many cities today, and utility efficiency programs are one of the resources regularly utilized by practitioners for immediate assistance with these issues. Neighborhoods experiencing growing numbers of African Americans, multifamily renters and low-income individuals are significantly more likely to bear the brunt of increasing energy burdens than their white and high-income neighbors. Many of these populations were already saddled with high energy burdens, making the increase notable. This is especially true in Atlanta and Denver. These results are consistent with many displacement narratives. Areas in Atlanta that are losing African American population are seeing statistically significant reductions in energy burden. Areas in Denver with falling numbers of renter-households are also seeing significant reductions. An increase in evictions in Atlanta also leads to a significant reduction in energy burden, suggesting that the new residents are in a better financial position than the prior residents.

One source of assistance currently available in each of the studied cities lies in the hands of the electric utility. Unfortunately, relying on the current cost tests analyzed above leaves large quantities of cost-effective and burden-relieving energy savings on the table. By relying on electric utilities to provide energy assistance to low-income neighborhoods based on traditional cost-tests, residents may be denied a more-equitable future. Addressing equity more substantively at this level will require new tests and approaches. Since equity, fairness, and sustainability are widely held public values in the United States, this outcome does not represent the public interest (Jorgensen and Bozeman 2007). In fact, recent surveys of Atlanta's residents show that they strongly believe that investments in energy efficiency emphasizing energy equity are the most critical for the future of energy in the city (Clean Energy Atlanta 2019). Utilities should not be expected to meet these needs on their own; other policies and programs need to be developed outside of the regulatory arena to improve energy equity. However, these findings show that if every household in the most burdened tracts of these cities received *all of the possible assistance* that passed the commonly-used TRC test, the median households in these tracts would still live above the conventional 6% threshold of being "overburdened" by energy costs.

Conclusion

Energy burdens are determined by a household's energy consumption, the price of electricity within a region, and household income. Because it is a function of income, energy burden primarily impacts low-income households, often forcing individuals to make choices between health and financial stability. Previous research identified poverty and race as indicators of higher energy burdens at various levels across the country. This research sheds light on how these issues are changing over time for three cities in very different contexts across the United States. Our findings suggest that for an individual living in Atlanta or Denver, race is a significant determinant of a household's energy burden. We also find that the cost tests performed by the utility do not take full advantage of the cost- effective efficiency potential.

Bill assistance and energy efficiency can counter the stresses of energy burden, with efficiency generally providing longer-lived, more robust solutions. Energy efficiency could assist with more sustainable and equitable outcomes if deployed strategically. These findings show that some communities in these cities have seen shifts in energy burden, with the problem exacerbated in areas with increasing levels of renters, African Americans, and impoverished populations. This suggests that business-as-usual is not a strategic application of energy efficiency funding towards fixing the broken systems that cause regular harm to frontline communities.

It may also be the case that a separate or new framework beyond the cost-effectiveness tests is needed to produce equitable outcomes in these cities. Relying on cost-tests to determine the quantity and focus of money spent on efficiency programs leaves less room for contextual decision-making regarding differing political and demographic spaces. The most-widely used, test, the TRC, would only achieve 7%, 8%, and 9% of the likely efficiency potentials for Los Angeles, Denver and Atlanta, respectively. Given the higher incremental cost of achieving low-income energy efficiency savings and that some of these utilities are incentivized based on demonstrated savings means that these potentials are likely overstated – the current regulatory context disincentivizes energy efficiency investments in these communities.

More research into the causes, correlates, and relationships driving or driven by energy burden is also a critical need. Our model uses evictions as a predictor of energy burdens, but it could also be that energy burdens are a predictor of evictions. Income may also show a variety of non-linear relationships to energy burden. Exploring these relationships would require different calibrations or new model constructs entirely, and should be the subject of future research.

Many policymakers and organizations interested in equitable outcomes recognize the importance of reducing energy burden and addressing the determinants of high energy burden and housing affordability more broadly. Regulatory constructs require changes if utilities are to be pivotal actors in advancing an equitable energy future, and for many cities, these issues are managed at the state level. Cities interested in solving these problems will likely find themselves simultaneously reaching towards higher levels of government and towards grassroots, community-based organizations. They may be engaging in unfamiliar arenas, intervening in cases at utility commissions and building new coalitions; indeed, this work is underway in some form in many places across the United States.

If and how these policy goals are pursued is a matter of energy justice and energy democracy. Increased attention to these issues is necessary if cities are to realize the opportunity to use energy efficiency as a least-cost pathway towards an equitable clean energy transition.

References

ACEEE: Evaluation, Measurement, & Verification. (Jan. 2020). Retrieved from https://database.aceee.org/state/evaluation-measurement-verification

American Community Survey (ACS). (2017). Retrieved from https://www.census.gov/programs-survey/acs

Annual Energy Outlook 2020. (n.d.). Retrieved from https://www.eia.gov/outlooks/aeo/

Berry, C., C. Hronis, and M. Woodward. 2018. "Who's Energy Insecure? You Might be Surprised." In Proceedings of the ACEEE 2018 Summary Study on Energy Efficiency in Buildings, 13: 1–14.

Brown, M. A., Soni, A., Lapsa, M. V., Southworth, K., & Cox, M. (2019). Low-income energy affordability in an era of U.S. energy abundance. Progress in Energy, 1(1). doi: 10.1088/2516 1083/ab250b

Choate, J., & Wolfe, M. (2011). National Energy Assistance Survey. November. http://neada.org/wp- content/uploads/2013/05/NEA_Survey_Nov11.pdf.

Cluett R, Amann J and Ou S 2016 Building better energy efficiency programs for low-income households American Council for an Energy-Efficient Economy (ACEEE), Report Number A1601

Colton R D 2011 Home Energy Affordability in New York: The Affordability Gap (2008–2010) (Albany, NY: Sew York State Energy Research Development Authority (NYSERDA))

Department of Energy (DOE): Residential Energy Consumption Survey. (2015).

Drehobl, A., & Ross L. (2016). Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low-Income and Underserved Communities. American Council for an Energy-Efficient Economy.

Fisher S. & Colton Public Finance & General Economics 2013 Home energy affordability gap Public Finance and General Economics (http://homeenergyaffordabilitygap.com/)

Gavryliuk, O., Walter, L., Shah, S., Paton, C., Behrendt, J., Banerjee, J., Henke, A., Lewein, J., Patterson, R., Poorvin, E., Rickert, A., Wang, W. Energy Cost Burden in NYC: Understanding the Implications of New York City's Climate Change Targets on Energy Cost Burden. Columbia University, 2018.

Hernandez, D., & Bird, S. (2010). Energy Burden and the Need for Integrated Low-Income Housing and Energy Policy. Poverty Public Policy, 2(4), 5-15. doi: 10.2202/1944-2858.1095

Hirst, E., & Brown, M. (1990). Closing the efficiency gap: barriers to the efficient use of energy.

Resources, Conservation and Recycling, 3(4), 267–281. doi: 10.1016/0921-3449(90)90023-w

Hoffman, I. M., Rybka, G., Leventis, G., Goldman, C. A., Shwartz, L., Billingsley, M., & Schiller, S. (2015). The Total Cost of Saving Electricity through Utility Customer-Funded Energy Efficiency Programs: Estimates at the National, State, Sector and Program Level.

Lazar, J., & Ken, C. (2013, October). A Rap Webinar. Montpelier.

Li, P. "Correctional analysis of energy burden and eviction rate." www.dukespace.lib.duke.edu. Duke University, Nicholas School of the Environment. 2019.

Lyubich, E. (2020). The Race Gap in Residential Energy Expenditures. Energy Institute WP, 306. (https://evalyubich.com)

MEEA EM&V. (n.d.). Retrieved from https://www.mwalliance.org/initiatives/policy/emv

Nadel, S. "For Existing Homes, energy efficiency often has better return on investment than solar." *ACEEE*, 21 May 2019, www.aceee.org/blog/2019/05/existing-homes-energy-efficiency.

Nadel, S., & Ungar, L. (2019). Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050. Washington, DC : American Council for an Energy-Efficient Economy.

National Action Plan for Energy Efficiency (2008). Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy Makers. Energy and Environmental Economics, Inc. and Regulatory Assistance Project.

National Residential Efficiency Measures Database Home Page. (n.d.). Retrieved from https://remdb.nrel.gov/

One in three U.S. households faces a challenge in meeting energy needs. (2018). Retrieved from https://www.eia.gov/todayinenergy

Porse E, Derenski J, Gustafson H, Elizabeth Z. and Princetl S. (2016). Structural, geographic, and social factors in urban building energy use: analysis of aggregated account-level consumption data in a megacity. Energy Policy, 96 179–92

ResStock Analysis Tool. (n.d.). Retrieved from https://www.nrel.gov/buildings/resstock.html

Ross, L., A. Drehobl, and B. Stickles. 2018. *The High Cost of Energy in Rural America: Household Energy Burdens and Opportunities for Energy Efficiency*. Washington, DC: ACEEE. www.aceee.org/research-report/u1806.

Rothstein, R.(2017).The Color of Law: A Forgotten History of How Our Government Segregated America. New York ; London: Liveright Publishing Corporation.

Schiller S. R., G. Leventis, T. Eckman, and S. Murphy. 2017. Guidance on Establishing and Maintaining Technical Reference Manuals for Energy Efficiency Measures. Prepared by Lawrence Berkeley National Laboratory for the State and Local Energy Efficiency Action Network.

Schwartz, L. C., I. M. Hoffman, S. R. Schiller, S. Murphy, and G. Leventis. Cost of Saving Electricity Through Efficiency Programs Funded by Customers of Publicly Owned Utilities: 2012–2017. 2019.

Teller-Elsberg, J., Sovacool, B., Smith, T., & Laine, E. (2016). Fuel poverty, excess winter deaths, and energy costs in Vermont: Burdensome for whom? Energy Policy,90, 81-91. doi:10.1016/j.enpol.2015.12.009

U.S. Dep’t Of Hous. & Urban Dev., Affordable Green: Renewing The Federal Commitment To Energy Efficient, Healthy Housing 9 (2012)

U.S. Energy Efficiency Potential Maps. (n.d.). Retrieved from https://www.energy.gov/eere/slsc/us-energy-efficiency-potential-maps

U.S. Energy Information Administration (EIA) Annual Electric Power Industry Report, Form EIA-861 detailed data files. (2018). Retrieved from https://www.eia.gov/electricity/data/eia861/