Relative Energy Burden: A Nuanced Approach to Measuring Energy Burden among Homeowners in the United States

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Research Problem

Energy burden remains a pressing issue in the United States, despite the plethora of energy alternatives available. Defined as the percentage of household income spent on energy costs, households are considered energy burdened when this figure exceeds 6% (Bohr & McCreery, 2020; Moore & Webb, 2022; Scheier & Kittner, 2022). Nationally, approximately 67% (25.8 million) of low-income households, defined as those earning ≤ 200% of the federal poverty level, face a high energy burden (Drehobl et al., 2020). Recent studies further reveal that about 16% of all households experience energy burden disproportionately burdening Black, Hispanic, and Native American communities (Scheier & Kittner, 2022). The consequences of high energy burden extend beyond financial strain, encompassing tradeoffs between essential household needs, housing instability, impacts on general well-being, and local economic development (Chen et al., 2021; Fabian et al., 2014; Drehobl et al., 2020; Hernández & Bird, 2010; Makhijani, 2021; Bohr, 2019).

Conventionally, energy burden research has emphasized demographic disparities and spatial distribution (Scheier & Kittner, 2022). While crucial for understanding vulnerabilities i.e. persons or households susceptible to high levels of energy burden, there exists a notable gap in the literature regarding metrics for quantifying energy burden. This gap is significant due to incongruities in the 6% benchmark. Metrics for measuring energy burden are typically categorized as subjective or objective (Agbim et al., 2020). While some studies have attempted to modify existing metrics or combine subjective and objective measures to capture energy burden on a larger scale, such as using surveys alongside conventional calculations (Agbim et al., 2020; Scheier & Kittner, 2022), these metrics remain inadequate in quantifying energy burden in the US.

This inadequacy stems from the failure to consider other essential household expenditures that impact a household's ability to afford energy bills. Real energy burden encompasses not only income and energy costs but also other vital expenses like housing, water, sewage, and taxes, which are currently excluded from calculations. Furthermore, it remains unclear how energy burden varies when accounting for these essential costs, particularly for vulnerable communities. To address these gaps, this study proposes an alternative metric for capturing household energy burden in the US, namely Relative Energy Burden (REB).

Relative Energy Burden, defined as the percentage of household income spent on energy costs after accounting for all other essential expenses, holds promise for identifying energy burden hotspots among low-income homeowners in the United States, particularly among minority and vulnerable populations. Given their low-income levels, these communities often struggle to afford other essential needs due to high energy bills. Therefore, this study aims to investigate how energy burden varies across counties and different socioeconomic, demographic, and minority groups in the US. Moreover, a better method for calculating energy burden is crucial for the delivery of energy-efficient housing projects in an equitable manner. By accurately assessing the energy burden faced by different demographic and socioeconomic groups, policymakers and stakeholders can design and implement targeted interventions to ensure equitable access to energy-efficient housing solutions (Miller, 2018).

Methods

The study utilized the American Community Survey's Public Use Microdata Sample (PUMS) dataset due to its household-level data and suitability for estimating both Energy Burden (EB) and Relative Energy Burden (REB). Data from the 5-year PUMS dataset spanning 2017 to 2021 was employed, presented through maps and descriptive analyses.

Data preparation for energy burden estimation

The PUMS dataset contains diverse variables including spatial, demographics, socio-economic data, and utility expenditure. Focused on homeowners, the dataset was first filtered accordingly. In order to estimate energy burden, 6 major variables were selected including monthly electricity and gas costs, yearly fuel cost apart from electricity and gas, annual household income, selected monthly owner costs as a percentage of household income and Disposable income. Derived yearly costs and geographic variables including PUMA (Public Use Microdata Area), State and Region facilitated county, state and regional level analysis. Homeowners with zero or negative income were excluded.

Estimating and Analyzing EB for Low-Income Homeowners

The Energy Burden (EB) was estimated as the ratio of total energy expenses (AEC) to yearly household income (HINCP) by adding ELEP_New, GASP_New, and FULP. Outliers were excluded, ensuring EB falls between 0% and 100%. Low-income homeowners were identified as having an annual income that is less than or equal to 80% of the state’s Median Household Income (MHI) according to the US Housing Act of 1937. EB is calculated for PUMAs or counties as the mean of households, and for states or regions as the average of PUMAs.

$$\text{EB} = \frac{\text{AEC}}{\text{HINCP}} \tag{1}$$

Estimating and Analyzing REB for Low-Income Homeowners

REB was calculated by dividing total energy costs (AEC) by disposable income (DI), after deducting essential costs like water, sewer, taxes, housing, fire, and hazard insurance. Similarly, Low-income homeowners were identified as having an annual income that is less than or equal to 80% of the state's Median Household Income (MHI). REB for PUMAs or counties and states or regions was derived from the average of all PUMAs. Outliers falling below 0% or above 100% are excluded. This comprehensive technique allows for accurate measurement of energy load levels at various geographic scales.

$$\text{REB} = \frac{\text{AEC}}{DI} \qquad (2)$$

Results

Regional and State level Analysis

Figure 1 displays energy burden levels across US regions based on the US Census Bureau's classification. Region 9, comprising Puerto Rico, exhibits the highest energy burden among low-income homeowners (22%), while the West region experiences the lowest burden (14%). The Northeast, Midwest, and South regions share a similar energy burden of 17%. Table 1 highlights states with the highest Relative Energy Burden (REB) within each region. Puerto Rico, Alabama, and South Carolina top the list in the South region with an average REB of 21%. New York leads in the Northeast (20%), and Alaska in the West (19%). In the Midwest, Nebraska faces the highest REB at 18%.

Table 1: **REB levels by Region and State in the United States**

Region		REB	State	REB
1	Northeast	17	NY	20
2	Midwest	17	NE	18
3	South	17	AL	21
			SC	21
4	West	14	AK	19
9	Puerto Rico	22	PR	22

REB Hotspot Analysis at County level

Figure 1 illustrates Relative Energy Burden (REB) results at the PUMA/county level across the US, categorized into four levels: Not burdened (0%-5%), Burdened (6%-20%), Highly burdened (21%-35%), and Extremely burdened (36% and above). The West and parts of the Southwest exhibit counties with energy-burdened low-income homeowners, including Alaska, New Mexico, Wyoming, and California. Hotspots, primarily in the Southeast and Midwest, feature highly and extremely burdened counties, such as Alabama and South Carolina. Puerto Rico shows counties with extremely burdened homeowners. Comparing with Energy Burden (EB) results in Figure 2, the US is predominantly characterized by energy-burdened counties for low-income homeowners, especially in the Southeast and Puerto Rico. The REB method identifies extremely burdened homeowners not captured by EB, emphasizing its efficacy in pinpointing severe energy burdens which is vital for equitable energy policy planning and targeted resource allocation for efficient housing project delivery.

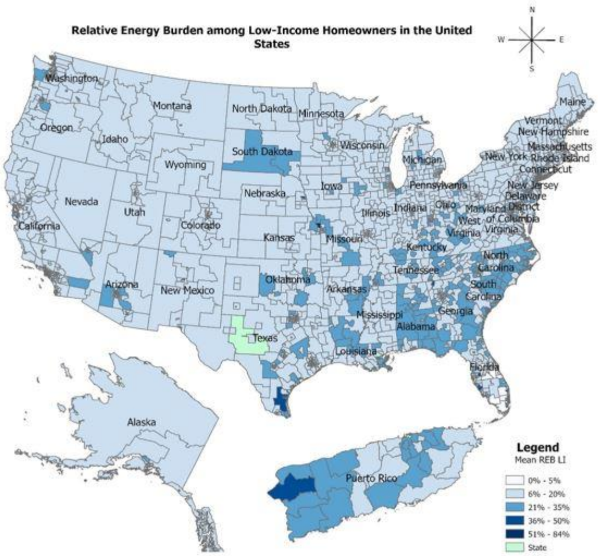

Figure 1: Relative Energy Burden (REB) among low-income homeowners in the United States (PUMS Dataset 2017-2021).

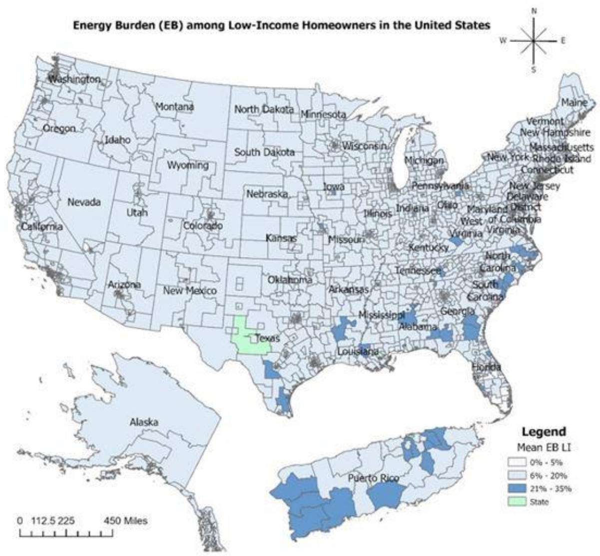

Figure 2: Energy Burden (EB) among low-income homeowners across in the United States (PUMS Dataset 2017-2021).

New REB Hotspots at PUMA/County level in the US

Using the REB method, 92 new PUMAs across 19 states were identified as energy burdened, differing from the conventional EB method's classification as seen in table 2. Over half of these hotspots were in California (57%), with Arizona, Colorado, Virginia, and Washington each contributing 4%. Fifty-two percent of states featured at least one new REB hotspot, predominantly categorized as energy or highly energy burdened. REB levels ranged from 6% to 26% for low-income homeowners, spread across all US regions, with a concentration in the South.

Table 2: New REB Hotspots for Low-income Homeowners in the US

Name	No. of new REB hotspots	%	Example of PUMA/Counties
AZ	5	5	101, 117, 123, 132, 203
CA	52	57	3712, 3717, 3764, 5915, 7317,
CO	4	4	803, 813, 817, 4104
DC	1	1	101
FL	1	1	5708
GA	1	1	4002
HI	1	1	100
IL	3	3	3209, 3401, 3418
MD	2	2	1002, 1007
MN	1	1	1403
MS	2	2	1000, 2000
MO	1	1	1806
NJ	1	1	407

NM	1	1	803
NY	1	1	3802
TX	6	7	1902, 1904, 4628, 5306
UT	1	1	35006
VA	4	4	10701, 59301, 59309, 59308
WA	4	4	11103, 11601, 11603, 11702
19	92	100	

Discussion and Conclusion

This nationwide investigation aimed to assess energy burden among low-income homeowners in the United States, introducing the Relative Energy Burden (REB) metric as a novel approach. REB, defined as the percentage of household income spent on energy costs after accounting for essential household expenses, offers a comprehensive perspective on energy burden. Analysis of the current 5-years PUMS dataset from 2017 to 2021 revealed regional disparities in mean REB, attributed to varying climatic conditions (Wang et al., 2021). Notably, Puerto Rico exhibited the highest mean REB levels, while the West region recorded the lowest, aligning with previous findings (Wang et al., 2021).

At finer geographical levels, such as PUMAs and counties, the Midwest and Southeast emerged as hotspots of high REB levels for low-income homeowners, corroborating studies on localized energy burden (Chen et al., 2022). However, the REB method identified new hotspots, particularly in California, underscoring the importance of granular analyses for targeted interventions. The study contributes theoretically by broadening knowledge on energy burden literature and emphasizing low-income homeowners across the US. Practically, it offers a detailed understanding of energy vulnerabilities at the county level, serving as a valuable tool for policymakers to inform federal housing and energy assistance programs through targeted interventions.

The findings of this study have significant implications for improving the delivery of energy-efficient housing projects in an equitable manner. By identifying regions and counties with high REB levels among low-income homeowners, policymakers can prioritize these areas for targeted interventions. These interventions may include the implementation of energy efficiency measures, such as weatherization programs and subsidies for energy-efficient appliances, to alleviate energy burden and improve housing affordability. Moreover, the REB metric can guide the allocation of resources to areas with the greatest need, ensuring that limited funds are utilized effectively and equitably.

In conclusion, the REB method provides a valuable tool for understanding energy burden among low-income homeowners in the United States. By incorporating essential household expenses into the calculation, REB offers a more comprehensive assessment of energy affordability. The insights gained from this study can inform policy decisions and resource allocation to improve the delivery of energy-efficient housing projects in an equitable manner, ultimately contributing to the well-being of low-income households nationwide.

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