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The Persistence of High Energy Burdens: A Bibliometric Analysis of Vulnerability, Poverty, and Exclusion in the United States

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The Persistence of High Energy Burdens: A Bibliometric Analysis of Vulnerability, Poverty, and Exclusion in the United States

Highlights:

- Bibliometrics offer a useful tool to uncover evolving patterns of U.S. energy burden
- Issues of equity, race and justice are increasingly linked to energy burden
- High energy burdens exacerbate health problems
- Forecast that arrearages and stress of bill repayments will be prolonged by Covid-19

1. Introduction

Even after decades of energy bill assistance, retrofit subsidies, and weatherization programs, low-income households in the United States (U.S.), on average, continue to spend a higher share of their income on electricity and natural gas bills than any other income group. The energy burden of low-income households is not declining, and it remains persistently high and onerous, particularly in the South, in rural America, and among minority households. Our portrait of the stress of paying high energy bills and fear of service termination is a perplexing problem in a country with abundant and low-priced energy.

This paper uses bibliometric methods to examine the persistent problem of high energy burdens among low-income households in the U.S. focusing on issues of vulnerability, poverty and exclusion. The literature in this area is broad and encompasses a wide range of themes and topics. However, studies often focus on siloed issues and stop short of examining interlinkages between different areas and policies that affect household energy burdens. We leverage the latest approaches in systematic literature review, and visualization to address this gap. We take a holistic view of the energy burden landscape within the context of the U.S. The paper presents the ecosystem of energy access analyzing both the interconnections between different research themes and the temporal evolution of research in different areas. We start by identifying key players and stakeholders in this landscape. Next, we pinpoint the dominant themes in the last decade of literature and how they connect with aspects of equity and justice.

The term “household energy burden” has become a dominant construct used by researchers focused on the high energy bills that challenge income-constrained U.S. households. The accepted definition of energy burden is “the percent of a household’s income spent on utilities for heating, cooling, and other home energy services.” Energy-burden studies rarely consider the cost of transportation energy, which is unfortunate given that a broader energy scope

would likely spotlight even bigger affordability challenges and would lay a foundation for predicting impacts of the expanding market share of electric light-duty vehicles.

The underlying causes of high energy burden identified in the literature can be divided into five main categories [1]. On the remedy side of the equation, many policies and programs subsidize improvements in energy efficiency and investments in renewable energy including for example, rebates and credits for smart thermostats, efficient appliances, and tax credits for rooftop solar systems. However, such subsidies are often inaccessible to low-income households – they are not "inclusive" – due to affordability barriers and limited tax liability against which tax credits can be credited. While "Energy Efficiency for All" initiatives[1] and low-income solar programs are being launched by coalitions of non-governmental organizations (NGOs), they are limited in scale and present documented barriers of access, information, and costs.

Temporary solutions such as bill payment forgiveness programs and other financial assistance are widely available; indeed, such assistance dwarfs funding for more sustainable solutions including grants for home retrofitting and the direct installation of weatherization measures [2-4]. Both types of programs (temporary assistance and subsidies for home retrofitting) both serve critical needs. Fortunately, they also often benefit from being linked together, as when recipients of bill payment assistance are subsequently offered home energy improvement assistance.

For more than 40 years, numerous programs and policies have been implemented in the U.S. to promote residential energy efficiency and reduce household energy costs [5]. Funding for such programs peaked in the era of the American Recovery and Reinvestment Act (ARRA) following the global economic recession in 2008. Now available funding levels are slightly higher than in the years before ARRA, reflecting modest increases in historic levels of weatherization funding and more substantial increases in low-income solar programs [6].

We use advanced bibliometric analytics to aggregate highly varied and disparate metadata to characterize the literature's treatment of energy affordability. Using bibliometric tools, we examine the network of decision makers, stakeholders, policy makers and other influencers' perspectives on this complex socio-economic problem. The paper then turns to an analysis of the influences and impacts of energy burden that have received the most attention over the past decade. The paper ends by examining recent trends relevant to energy cost disparities and draws conclusion and implications with respect to future needs that may be evolving in response to the challenges of the coronavirus and climate change.

2. Methodology and Key Questions

Peer-reviewed and grey literatures were identified using the Web of Science database and a syntax of keywords including synonyms of three attributes: (1) energy efficiency and solar energy, (2) low-income households and poverty, and (3) data analysis and evaluation. This triad

[1] https://www.energyefficiencyforall.org/

of issues reflected the interests of the sponsor of this research, the U.S. Department of Energy, which was seeking an up-to-date review of the U.S. literature covering these topics for the purposes of its strategic planning.

To accomplish the review, we used the key word string connecting (1), (2), (3) using the AND Boolean operator and terms within each attribute using the "OR" operator. The following syntax was used to identify journal articles that combined three dimensions:

(1) a focus on low-income households (low-income OR "low income" OR "subsidized housing" OR equity OR poverty OR "fuel poverty" OR "energy justice" OR socioeconomic OR "environmental justice" OR "consumer access" OR affordable OR "energy burden")

(2) coverage of energy efficiency or behind-the-meter low-carbon energy supply ("energy efficiency" OR "energy efficient" OR household "space cooling" OR household "air conditioning" OR household "space heating" OR "energy conservation" OR "energy retrofit" OR "energy improvements" OR weatherization OR weatherisation OR "low carbon" OR solar OR "solar panel" OR "solar panels" OR photovoltaic)

(3) analysis of the costs and benefits of alternative solutions ("program evaluation" OR efficacy OR effect OR cost-benefit OR "cost benefit" OR "benefit cost" OR benefit-cost OR analysis OR "policy analysis" OR "programme evaluation" OR impact OR incentive)

Overlaid on this rubric were criteria that at least one author had to be from the U.S., and the papers had to be published in the 2010-2019 timeframe, resulting in 270 peer-reviewed publications. These were "culled" for out-of-scope citations and also "mined" for additional references by examining the citations embedded in the original 270 publications. In addition, a rigorous external review process identified additional documents, particularly government reports. The result is a curated set of 183 rigorously reviewed publications summarized in an annotated bibliography [7].

Visualizing these findings provides a useful lens into the temporal dynamics and evolving topic clusters related to energy burden. The VOSviewer software tool developed by the Centre for Science and Technology at Leiden University makes it possible to visualize a set of documents and find linkages based on metadata including: citation networks, keyword co-occurrence and co-authorship among other bibliometrics [8]. This technique is sometimes called "science mapping" referring to the resulting visualizations that consist of nodes and edges. Nodes are data types including articles, authors, or keywords, for example, while edges describe links between these nodes. Van Eck and Walton [8] list over one hundred examples of technical and applied papers that utilize VOSviewer. Recent work using VOSviewer software varies widely including research on energy efficiency [9], patent activity related to wind energy [10], and building control research [8, 11]. Using both distance-based and timeline-based VOSviewer functions are part of this bibliometric study.

By visualizing and classifying relationships between topics, our approach reduces the challenging issue of information overload. Our software visualization approach improves

legibility and uncovers relationships within the bibliographic dataset. This combination of visualization and bibliometric analysis hopefully makes our findings more robust and more comprehensible to broader audiences.

This research posits three key questions for the aggregated literature review. First, what is the stakeholder ecosystem that influences the energy burden of low-income households, and have any key parts of this ecosystem been largely overlooked in the literature? Second, what influences and impacts on energy burden have received the most attention in the literature, and are there any important gaps? Finally, what trends have emerged most recently in this literature?

3. The ecosystem of key decision-makers and stakeholders

The socio-economic drivers for the highly fragmented affordable housing market (Figure 1) are impacted and championed by a range of stakeholders and advocates that influence both energy costs and energy-efficiency investments. The extent that the literature has examined these stakeholders is characterized by how often they are mentioned in the research abstracts of the 183 publications analysed. For details behind these findings, see the recently released report by Oak Ridge National Laboratory [1].

Being the principal supplier of energy services, it is not surprising that utilities are mentioned most often. One pertinent fact uncovered in our review, is that, on a per household basis, utility companies spend less on energy-efficiency programs for low-income households than other income groups.

Government agencies are also mentioned often in the literature reviewed, reflecting the administrative and regulatory functions they serve, which influence most stakeholders to varying degrees. Their roles are mentioned in nearly every abstract. While federal programs are large providers of bill assistance and weatherization assistance providing backbones for many additional partners to utilize, our review concludes that many government-funded clean electrification and green energy initiatives are largely inaccessible to low-income households because of financial constraints and limited tax liabilities. This lack of low-income inclusion and engagement has motivated recent campaigns to foster “equity-focused” clean energy planning in the U.S.[2]

Based on our tally, community-based groups and local NGOs are also key stakeholders. The numerous papers discussing their roles as partners in the delivery of weatherization and solar initiatives underscore their unique ability to reach underserved markets. On a more modest scale, financial institutions, realtors, manufacturers, and contractors are examined in only a few dozen of the 183 publications. Still, that is more often than the treatment of building and property managers, which go entirely unmentioned in the 183 abstracts, despite their decisive role. Similarly, building owners and landlords are mentioned only 10 times, indicating that

[2] https://www.wri.org/our-work/project/clean-energy/equitable-clean-energy-planning

these stakeholders have received limited analysis in this body of literature. In low-income communities where families are often renters in apartment complexes or public housing, the role of these key influencers represents a key gap in the literature. This is despite the long-standing body of research describing the landlord/tenant split incentive and the difference between renter and homeowner investments in energy-efficiency. Figure 1 provides a conceptual framework for characterizing how markets, programs, and policies operate as a mutually reinforcing network influencing low-income home energy affordability. By looking holistically at all of the players, it is possible to better identify opportunities for leveraging and coordination to provide a more effective and efficient system of assistance.

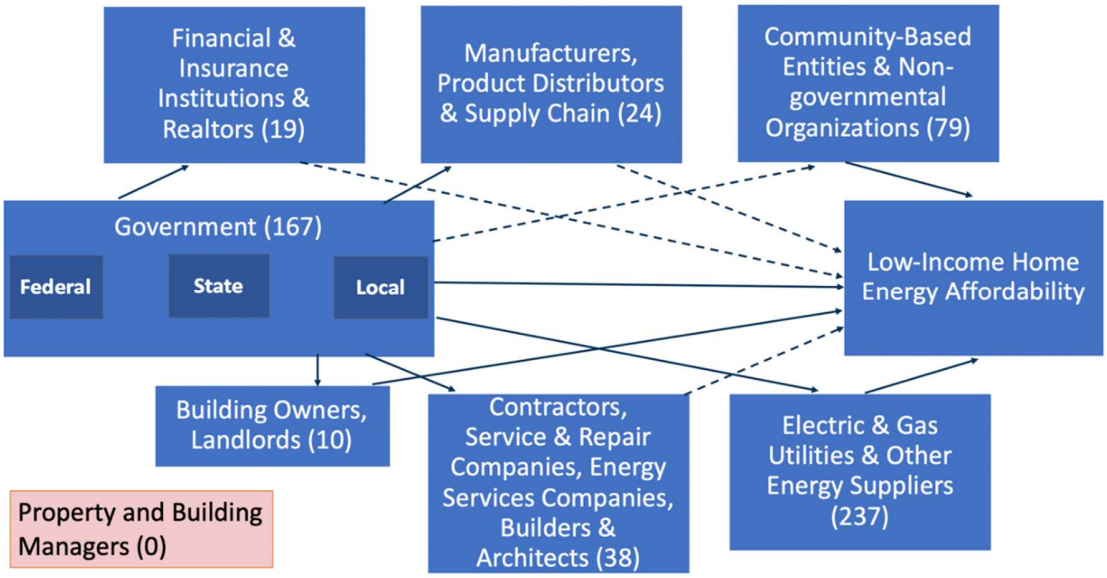


Figure 1. The array of stakeholders in the fragmented low-income housing market. (Source: Authors) Note: Solid lines represent strong levels of influence and dashed lines represent weaker connections.

4. The influences and impacts of energy burden that have received the most attention

Figure 2 presents a "network visualization" of the 183 publications based on their titles and abstracts. It reveals a six-cluster network focused on energy efficiency (green), electricity (red), government programs (purple), climate and energy insecurity (blue), health (yellow), and sustainability (orange). Of all the stakeholders, government agencies and programs are dominant, referenced in purple.

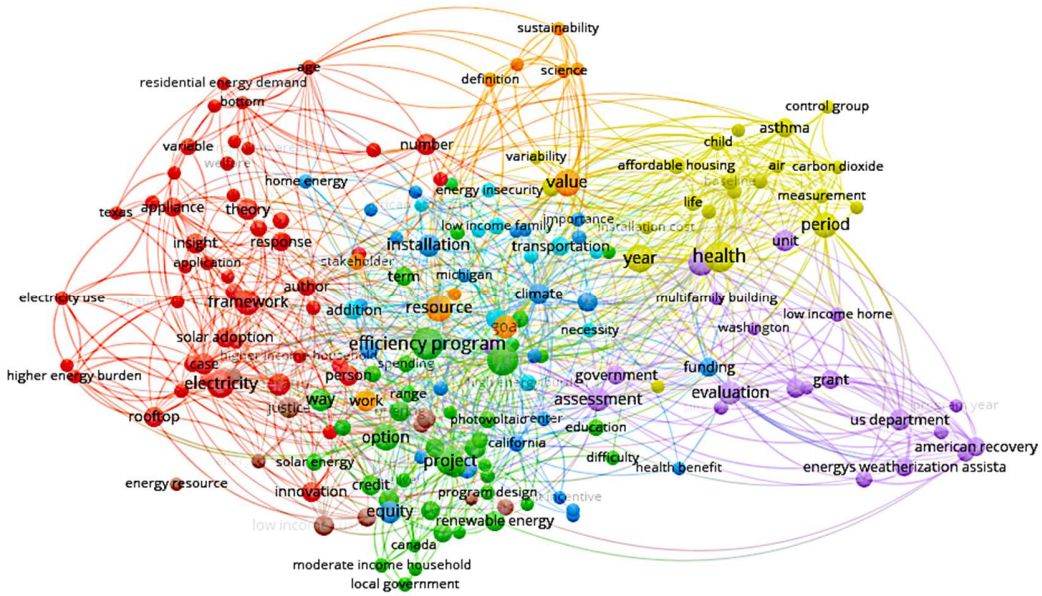


Figure 2. Network visualization of 183 publications (Source: Authors)

5. Trends emerging in recent years

In Figure 3, the temporal bibliometric analysis and associated literatures highlight an abundance of valuable recent insights. This network was examined using an "overlay visualization" to identify the words most closely linked to keywords of interest. The term "burden" was considered first, and subsequent terms were studied to clarify their relationships to energy burden. By using chronological color-coding, our analysis further refines the identity of trends and gaps by assessing the years in which terms appear in the literature (Figure 3). Three overlay visualizations emanate from the words: health, solar-photovoltaics, and equity-justice-African American.

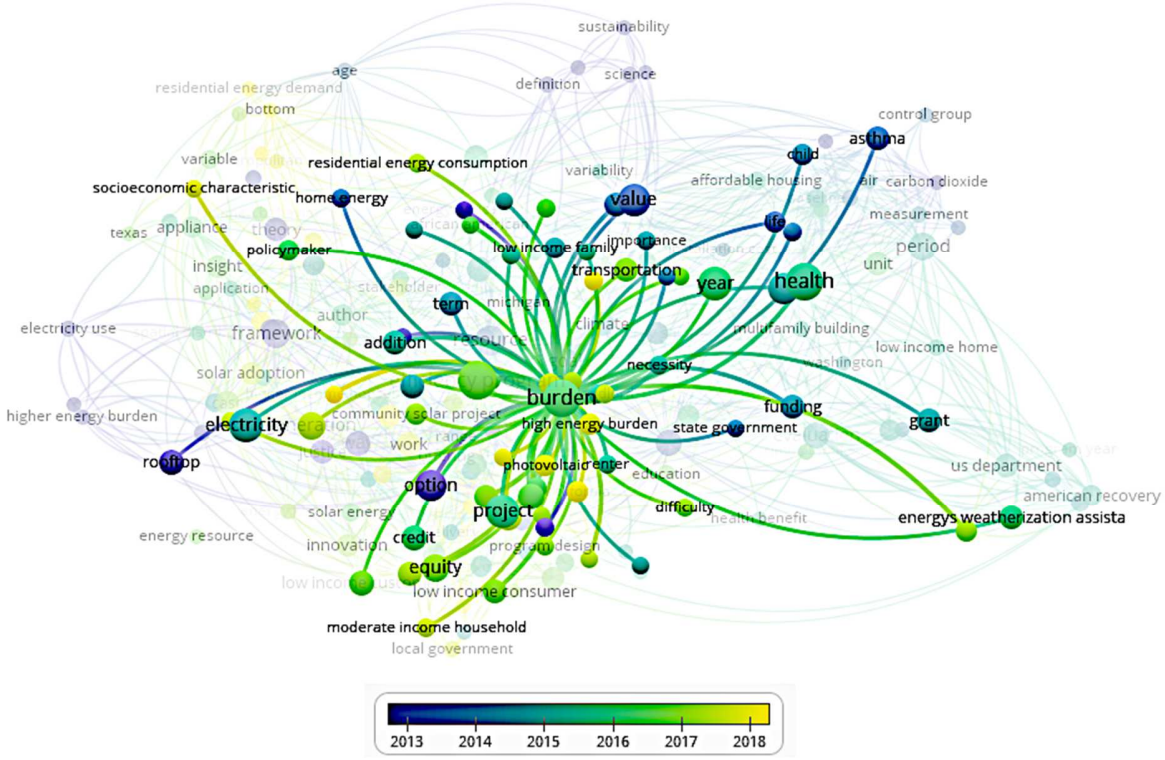


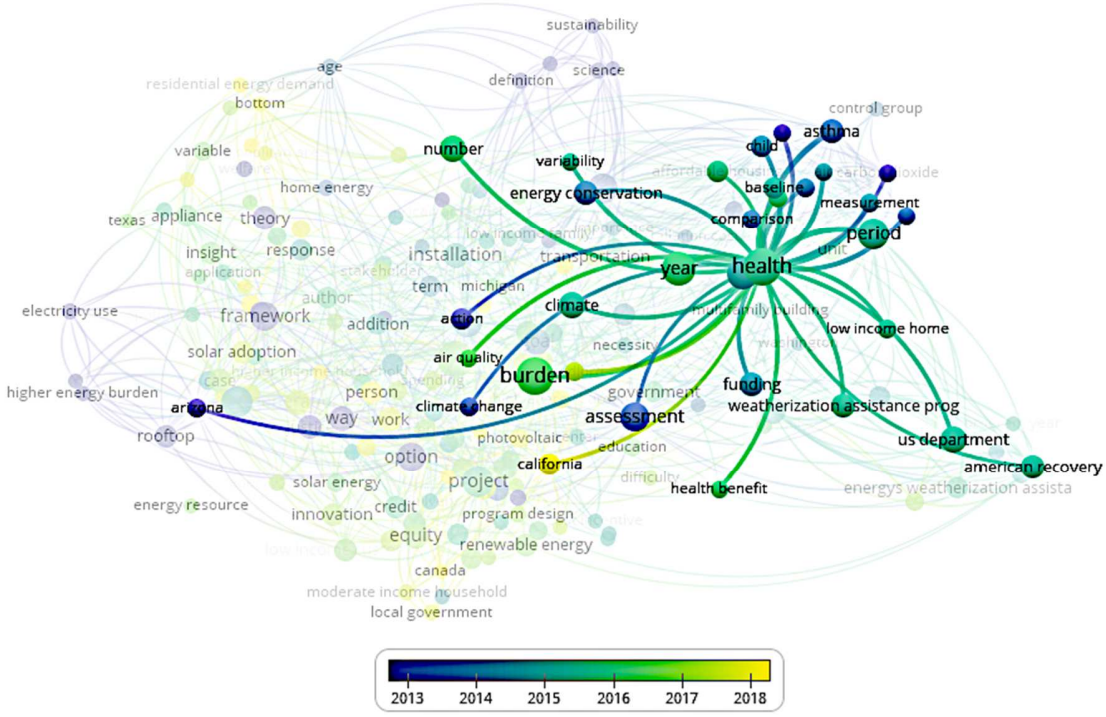
Figure 3. Overlay visualization of energy burden in the annotated bibliography (Source: Authors)

Numerous studies published over the past decade have highlighted the **health** consequences of the inadequate energy infrastructure that is typical of affordable housing in the U.S. (Figure 4). Outdated space conditioning equipment and poorly insulated roofs, walls, and foundations characterize this building stock, and these can cause or exacerbate the health problems of occupants. Exposure to carbon monoxide poisoning and other indoor air pollution also can result from inefficient, unvented, and subserviced heating equipment [12]. Other health issues include lead exposure, thermal discomfort and respiratory problems such as asthma [13]. Respiratory illnesses and thermal discomfort are associated with older HVAC systems, which characterize much of the low-income housing stock. Living with energy insecurity represents the consequences of stressors, fears and even mental health related to the inability to pay energy bills and the real potential disconnection of electricity and home gas heating utility services. These effects are amplified for groups vulnerable to additional underlying health issues combined with financial limitations [14].

At a time when health care systems across the country are stressed with meeting the needs of those afflicted with the Covid-19 pandemic, substantial evidence links energy burdens to conditions that can increase vulnerabilities to the coronavirus and psychological stress associated with the threat of losing electric connections due to non-payment [15]. Many utilities have initiated moratoria against disconnections in the midst of the pandemic. After these moratoria are lifted, utilities will face unparalleled levels of economic and social crisis

among their customers. It is uncertain how arrearages will be managed during what will likely be an extended period of increased debt and extended repayment. It is not clear what kinds of alternative payment and assistance utilities might offer, and how other stakeholders can assist.

Figure 4. Network visualization of health in the annotated bibliography (Source: Authors)



Solar photovoltaics have been addressed increasingly in recent years in the context of low-income energy affordability (Figure 5). Nationwide, residential rooftop solar systems have been installed primarily on owner-occupied single-family housing owned by affluent families. Because they possess less disposable income, low-income households find it difficult to invest in solar energy, and because they often live in older poorly maintained housing, their rooftops may be unsuitable for solar without first undergoing repairs. In addition, federal solar tax credits are a poor fit for households that do not have large tax liabilities.

Towns and cities have launched “Solarize” programs to encourage more widespread solar investments by their citizens. These programs are able to reduce the barriers and headaches of installing solar in residences by providing pre-approved contractors and standardized contract terms [16]. However, they have not been able to penetrate the low-income marketplace.

“Solar for All” programs, in contrast, offer subsidies and various incentives to enable low-income households to afford solar systems. By becoming “prosumers,” households can reduce their energy bills and burdens. The ability to reduce power bills with the addition of rooftop solar depends on the utility’s net metering specifications. With high buyback rates, households are able to benefit more than when utilities purchase the household’s excess generation at low rates. Utilities often argue that buyback rates should be keyed to their least cost supply options

(which in today's market is typically natural gas combined cycle power systems), without crediting solar for its environmental attributes or the magnitude of its on-peak vs off-peak generation.

Successful solar programs operating in low-income communities have often benefitted from community support, which has been particularly instrumental in bringing solar to multifamily buildings [17]. Community organizers have also played key roles in encouraging the pro-social dimensions of solar programs [18-21].

Case studies of programs operating in Colorado, New York and Michigan have shown that state-wide solar programs can be successful when they include mechanisms to also promote energy-efficiency investments. These bundled approaches can significantly decrease energy burdens while also mitigating the risks associated with installing solar on low-income housing [22]. In the pilot program called SASH (Single Family Affordable Solar Housing), including electric vehicles reduced costs further [23]. Vermont has broadened the scope of integrated programs even further by adding home energy storage to the triad of energy efficiency, solar rooftops, and electric vehicles. Recent studies have also found evidence that despite high solar rooftop potential, many LMI communities might not be able to leverage the benefits for a variety of reasons such as income, demographic characteristics, language proficiency, age of the housing stock, and internet access [21]. As such, understanding local conditions and "dynamics", and accounting for disparities along social and cultural characteristics can help design equitable and more successful programs.

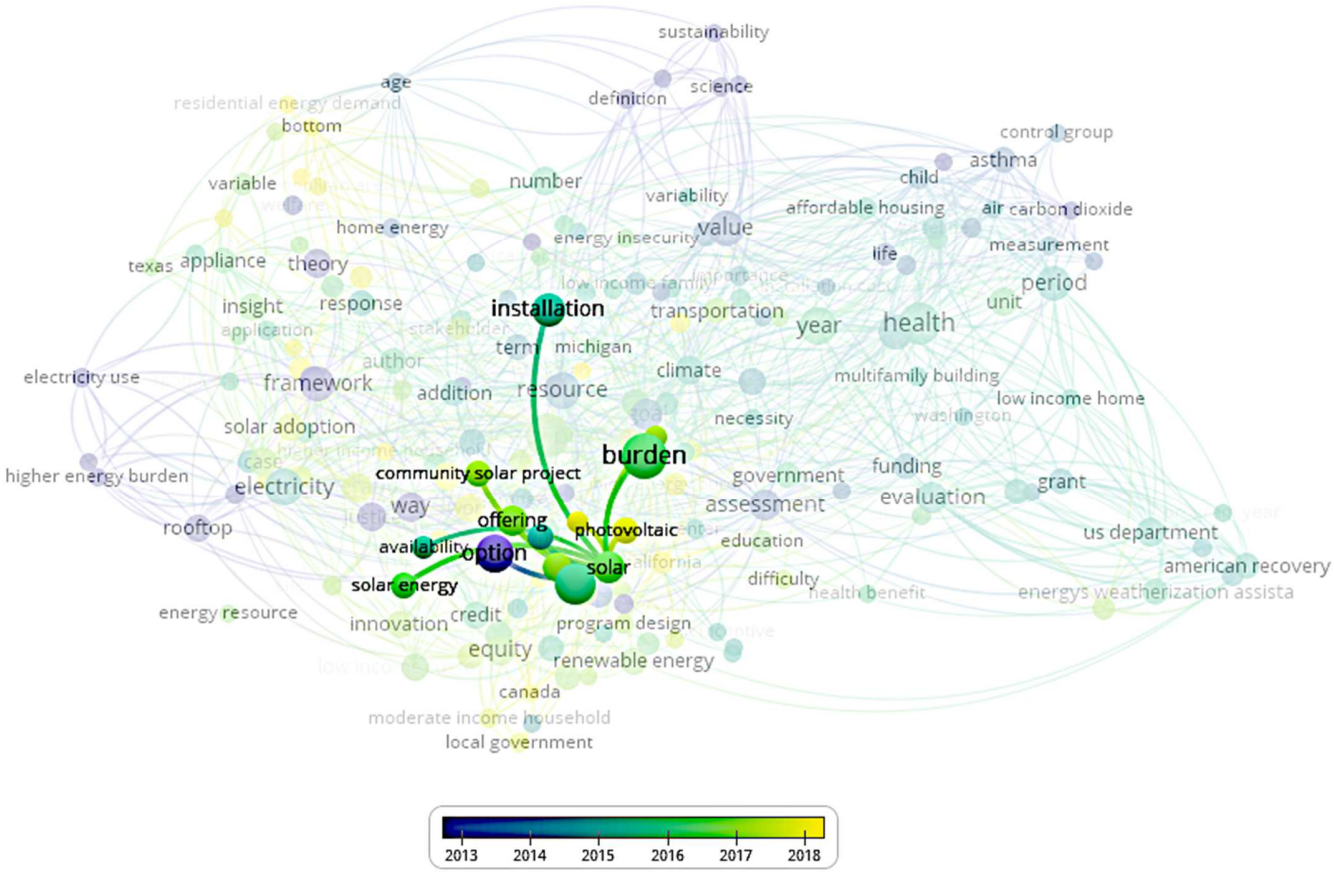


Figure 5. Network visualization of solar in the annotated bibliography (Source: Authors)

Equity, race, and environmental justice are increasingly being recognized as issues at the intersection of energy insecurity and energy consumption (Figure 6) [24]. Hernandez et al. [25] and Bednar et al. [26] find that African Americans shoulder greater utility expenses and have higher energy-use intensities (EUIs) than mainstream Americans, and the same is true of Hispanic households. Energy insecurity for black households with children, documented in recent studies, are more likely than other demographic groups to be overburdened with utility costs [27].

Research on advanced energy technologies document many of the same patterns of disparity. For instance, Sunter, Castellanos, and Kammen [28] 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.

The underlying causes of these patterns are complex. Historical housing injustices that include the Jim Crow laws are one root cause of racial segregation. Since that time, the wealth inequality gap – that is, the income disparity between low-income families and more affluent Americans – is growing overall throughout the U.S., and the gap is particularly large for minority

groups [28]. People of color, indigenous populations, and immigrants also typically experience limited access to a range of resources. Thus, the correlation between race, ethnicity, and class should be factored into energy program design and public policy making [28, 29].

For those on fixed incomes and for households with children, the challenges of acute energy insecurity are particularly severe [30]. After controlling for income, Hernandez, Aratani, and Jiang [31] found that disproportionately more than any other group, black households with children were more likely to experience energy insecurity. Kontokosta, Reina, and Bonczak [27] examined an extensive database of census block groups spanning five U.S. cities. They concluded that very-low-income residents (≤50% AMI) in minority neighborhoods had energy burdens that were 1.6% higher relative to households living in predominantly non-hispanic white communities with the same income levels [16]. Our literature analysis identified public policy design as a central strategy in equity management. When solar buy-back payments are keyed to retail rates, for example, net metering shifts costs from solar owners to lower-income ratepayers [32]. These historically troubling trends highlight that the increasing use of renewable energy, now underway in many communities across the U.S., could further exacerbate energy burden inequities and uneven power dynamics [33]. The appearance of this debate in the literature highlights how equity has increasingly been considered both in the literature and in energy program planning [14].

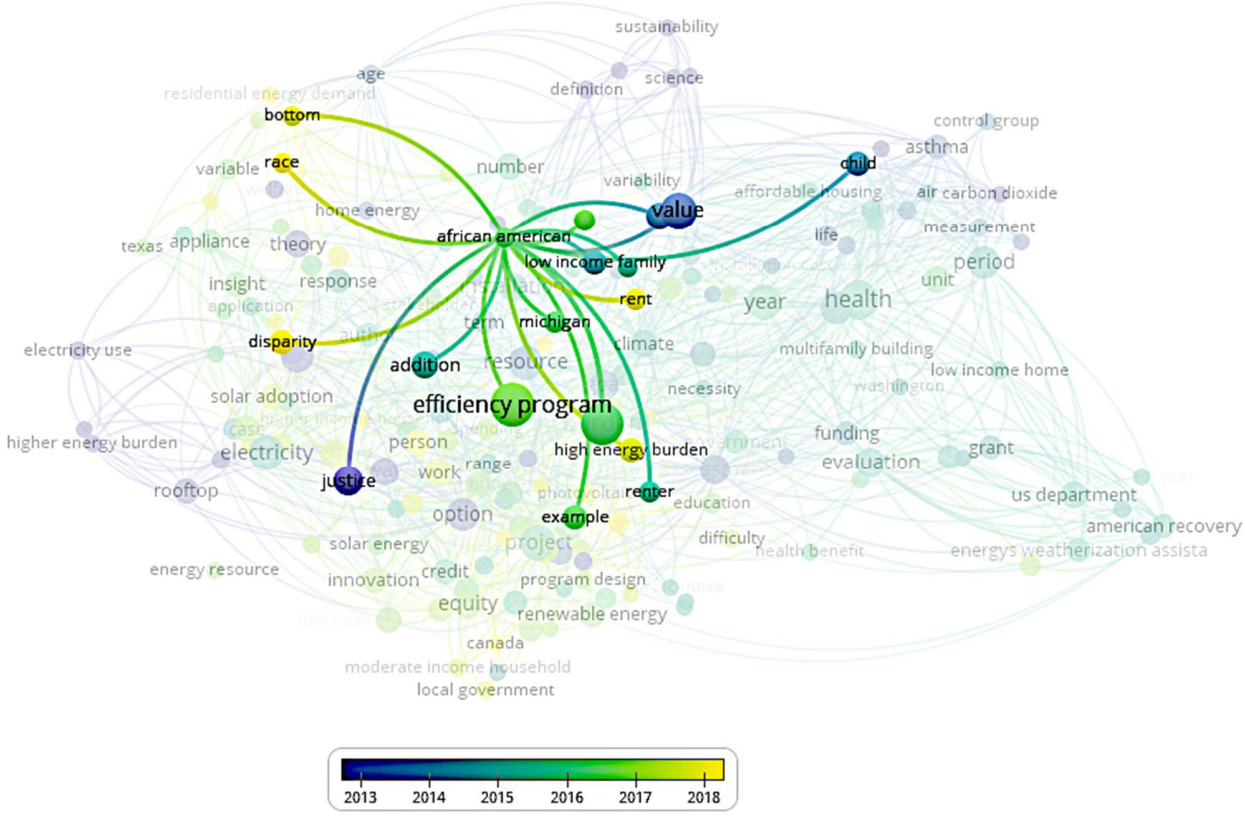


Figure 6. Network visualization of African American issues in the annotated bibliography (Source: Authors)

6. COVID-19 and the fragile circumstances of energy-burdened communities

Substantial and growing academic and industry literatures document the important determinants of low-income energy burden—its magnitude, incidence, and solutions [15, 34]. These insights are needed now more than ever with so many households facing multiple health crises including coronavirus, inadequate housing, unemployment, and natural disasters intensified by climate change. The focus on energy burden, and what can be done about it, is critical today as COVID-19 introduces a new layer of financial stress and climate change risks that challenges the transition to a clean energy future and is likely to be long-enduring. We. Predict that arrearages and stress of bill repayments will be prolonged by Covid-19.

The uptick in home working, schooling, exercising and cooking during the COVID-19 pandemic may stimulate a future with more home-based activities and hence higher home energy bills. The home environment may increasingly be a dominant determinant of society's health and prosperity. Similar to limited participation in energy rebates and the other initiatives, the energy-stressed low-income population faces the same challenges with COVID-19 – lack of adequate finances, limited internet connectivity, and constrained access to resources further limiting their capability to cope and adapt to the pandemic. These impacts that are home-based will be different for people of color who are disproportionately in a service economy where it is less likely for these households to have home-based employment.

7. Conclusions

To conclude, research on low-income energy burden and affordability spans decades, covering several themes along social, economic, and environmental dimensions, including public policy that can reflect systemic racism. This paper leverages recent advances in visual bibliometric analysis to identify the ecosystem of stakeholders in the area, the dominant themes, and temporal evolution of this area in the context of the U.S.

7.1 Landscape

We find that while several stakeholders play an important role in decision making, others who could play a key role tend to be overlooked in U.S. research on energy burdens. This understudied group of stakeholders includes building owners and landlords, property and building managers, financial institutions, realtors, manufacturers, and contractors. Yet these players are critical in determining the type of household construction, funding structure, utility payment options and viability of building upgrades but remain largely unexplored in current studies in the U.S.

7.2 Dominant Themes

While most analysis appears to be siloed and focused on one topic at a time across the range of research products, we nonetheless identify some interconnected themes. We find six clusters of research areas - energy efficiency, electricity, government programs, climate and energy insecurity, health, and sustainability. Energy efficiency tends to be intertwined with analysis of electricity consumption and time-of-use load management. Linkagea between energy burden and health also emerges as an important broad theme; many studies have examined the health co-benefits of weatherization assistance, improved HVAC systems and implications on respiratory health.

7.3 Temporal Evolution

While the themes identified in section 5 remain dominant throughout the period of study, some new themes have emerged as result of new government programs, increased technological feasibility, and the recent expansion of concerns about energy equity and justice. The emergent themes include solar photovoltaics, race and diversity, and the need for "equity-focused" clean energy planning. Recent literatures are also increasingly connecting climate change, energy burden, and health with implications for the Coronavirus pandemic.

8. Discussion

The last decade has produced a large and expanding literature on low-income energy burden. With the assistance of advanced bibliometric analytics, we offer some broad conclusions.

Energy burden is higher among low-income households than other income groups; it is not declining, and it continues to be high in particular geographies and socio-economic demographics. At the same time, many low-income households find it difficult to access subsidies to upgrade their energy equipment. This gap in energy justice continues to persist even as the country transitions to cleaner forms of energy [24].

Scalable approaches to reduce low-income energy burden require linking programs and policies to tackle the complex web of causes and impacts faced by households with limited resources. Two distinct opportunities exist: inter-agency cooperation and integrated technology-policy approaches.

Both funding and execution will require finely meshed and interwoven delivery systems that engage all the stakeholders shown in Figure 1. A coordinated approach to home energy, health, safety, and housing that integrates programs across geographies, race, and ethnicities could reduce low-income energy burden while delivering numerous other benefits to both current and future generations. If designed with equity in mind, the U.S. transition to a new energy economy could offer low-income households the opportunity to meet their energy service requirements more affordably.

Approaches of the past aimed at addressing the problem of affordable energy have been insufficient and, in some cases poorly designed. Despite the implementation of long-standing federal commitment to bill assistance, retrofit subsidies, and weatherization programs, low-

income energy burdens have not decreased. The result is a mystifying problem of high energy burdens in an age of abundant and low-priced electricity and fossil fuels in the U.S. New approaches are needed to create supportive markets and policies that can move all of society to a more sustainable, healthy, resilient and affordable energy future.

Acknowledgment

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Appendix:

For archiving purposes, this is the methodology used in VOSviewer:

Create a map based on text data
Read data from RIS file created by EndNote: Citations_01-08-2020.ris
Extract terms from title and abstract fields
Binary counting method (1 count for each title or abstract with a term)
Minimum number of occurrences of a term = 3
Of the 318 terms that resulted, select the 60% most relevant
191 terms resulted.

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