

**BEFORE THE WASHINGTON  
UTILITIES & TRANSPORTATION COMMISSION**

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION,

Complainant,

v.

PUGET SOUND ENERGY

Respondent.

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DOCKETS UE-220066, UG-220067, and UG-210918 (*Consolidated*)

**DAVID KONISKY  
ON BEHALF OF THE  
WASHINGTON STATE OFFICE OF THE ATTORNEY GENERAL  
PUBLIC COUNSEL UNIT**

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**EXHIBIT DK-4**

Environmental Research Letters Article The Persistence of Household Energy Insecurity  
during the COVID-19 Pandemic

**December 8, 2023**

# ENVIRONMENTAL RESEARCH LETTERS

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## The persistence of household energy insecurity during the COVID-19 pandemic

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## LETTER

The persistence of household energy insecurity during the  
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E-mail: [dkonisky@indiana.edu](mailto:dkonisky@indiana.edu)**Keywords:** energy insecurity, low-income households, COVID-19 pandemicSupplementary material for this article is available [online](#)**Abstract**

This study analyzes household energy insecurity in the United States during the first year of the COVID-19 pandemic. Previous research is limited by mostly cross-sectional research designs that do not allow scholars to study the persistency of this specific type of material hardship. We fill this gap by analyzing data from an original, nationally-representative, panel survey of low-income households. We find high levels of energy insecurity during the first year of the COVID-19 pandemic, especially during the initial months when the economic dislocation was at its height, and that many low-income households experienced it on multiple occasions during this period. We also identify disparities: households with people of color, very low-income, children aged five years and younger, with someone who relies on an electronic medical device, and those living in deficient housing conditions were more likely to experience energy insecurity. Households with these characteristics were also more likely to suffer from energy insecurity on a persistent basis through the first year of the pandemic.

**1. Introduction**

The economic disruption from COVID-19 was severe in many parts of the world, particularly during the early months of the pandemic, when the spread of infections and rising fatalities forced governments to impose preventative measures, such as stay-at-home orders, business closures, and strict limits on public gatherings. In the United States, the COVID-19 pandemic resulted in one of the worst recessions in the nation's history. The economy contracted nearly 20%, and tens of millions of people lost their jobs [1], forcing many American families into material hardship and exacerbating existing inequalities in income and well-being [2].

People who experience material hardship, especially when caused by sudden and unexpected economic shocks, often face difficult choices about how to manage their financial obligations [3]. Monthly mortgage or rent payments, food and medical needs, and other basic household necessities can become difficult to meet, particularly for people

in the lowest income groups. Scholars have studied people's experiences with myriad—and inter-related—forms of insecurities that result from material hardship, including housing insecurity and the threat of eviction [4], food insecurity [5], limited access to medical services [6], and difficulty in paying bills [3, 7].

In recent years, scholarship has also increasingly focused on energy insecurity and poverty, or the inability of a household to meet its basic energy needs because of financial hardship [8–12]. In the U.S. context, research has established that household energy insecurity is prevalent, particularly among vulnerable population segments [13–15]. Research further shows that high financial energy burdens increase the risks of poverty [10], and that energy insecurity can have detrimental consequences for well-being, including adverse physical and mental health effects [16–20].

There is reason to believe that the specific circumstances of the COVID-19 pandemic may have exacerbated household energy insecurity [21]. The preventative public health measures imposed to curtail

the pandemic not only led to economic disruption but also changed energy consumption patterns. A study of smart meter data in Arizona and Illinois, for example, found that residential energy use increased while commercial energy use declined, reflecting that people spent more time at home during this period, whereas businesses were required to curtail hours or shutdown altogether [22]. Moreover, these consumption changes were starker for populations already more likely to experience higher energy burdens [23] and carry utility debt [24, 25], particularly people of color and low-income households [22, 26].

Prior studies have analyzed measures of energy burden or energy insecurity from surveys, such as the U.S. Energy Information Administration's Residential Energy Consumption Survey (e.g. [12, 27–30]), the U.S. Census Bureau's American Community Survey (e.g. [31, 32]) and American Housing Survey (e.g. [33, 34]), and the University of Michigan Institute for Social Research's Panel Study of Income Dynamics (PSID) (e.g. [35]). Although these surveys provide information at the household level, most do not include geographic identifiers below the regional or state level, making it difficult to account for local factors. Importantly, these surveys rely on cross-sectional research designs (the PSID is an exception), which means they only capture relationships between household characteristics and energy insecurity at a single snapshot of time. Crucially, cross-sectional studies neither provide analytical leverage to identify factors associated with persistent energy insecurity nor do they account for temporal factors that are correlated with energy insecurity, such as seasonality and its accompanying variations in temperature, policy changes, and local-level economic conditions. Other work examines longitudinal datasets, such as the Women's Employment Study [36] and the Survey of Income and Program Participation [37, 38], to examine utility hardship, but research to date has yet to both employ a national-level, panel dataset and multiple dimensions of energy insecurity distinctly from other essential expenses.

In this study, we address these limitations through an analysis of an original panel survey that measures household energy insecurity among low-income Americans over time. Among other factors, the survey measures whether people report being unable to pay their energy bills, receiving a notice of service shut-off, or being disconnected from their service altogether. Several additional features of the survey design warrant emphasis. First, the survey provides household-level data, including measurement of important attributes that past work has shown to be associated with higher energy burdens and increased rates of energy insecurity, such as household composition and physical housing characteristics. Second, the survey studies the experiences of a nationally-representative sample of low-income

households, which enables a focus on households that are most likely to be vulnerable to energy insecurity yet is still broad enough to investigate the effects of other factors like race and medical vulnerability. Last, the panel research design allows for the identification of both short-term and persistent household energy insecurity, and, therefore, an analysis of the factors common and unique to each circumstance.

Our analysis reveals high levels of household energy insecurity among low-income households in the United States during the first year of the COVID-19 pandemic, and especially during the initial months when the economic dislocation was at its height. Moreover, we find persistence in household energy insecurity—that is, for most households who experience energy insecurity, it was not a one-time event but rather a circumstance that they experienced on a recurring basis. Consistent with past studies, we further find considerable disparities; people of color and those with particularly low-income were more likely to experience energy insecurity, as were households with children age five years and younger, with someone who relies on an electronic medical device, and those living in deficient housing conditions. Households with these same characteristics were also more likely to suffer from energy insecurity on a persistent basis through the first year of the pandemic.

## 2. Survey data

To examine household-level energy insecurity during the first year of the COVID-19 pandemic in the United States, we designed a nationally-representative, longitudinal survey of low-income households. The survey was administered in four waves between May 2020 and June 2021. The first wave of the survey was timed to capture conditions during the initial month of the economic dislocation resulting from government imposition of public health measures to limit the spread of COVID-19, with subsequent waves designed to follow-up with respondents regularly over the calendar year. The sample consisted of individuals residing in households with incomes within 200% of the Federal Poverty Line (FPL). In 2020, this equated to \$25 520 for an individual, and \$52 400 for a family of four [39]. The first wave of the survey had 2813 respondents, with the subsequent three waves having 2247, 1670, and 1378 respondents, respectively. We apply survey weights to each wave, assuring that the sample remains nationally-representative of low-income households in the United States.

The principal aim of the survey was to measure and explain household energy insecurity. Consistent with recent studies [13–15] and other surveys, we included several main indicators of energy insecurity: (a) inability to pay an energy bill; (b) receipt of a shutoff or service termination notice;

and (c) actual disconnection from service. For each indicator, we asked respondents to report in which month it occurred alongside a set of questions about what they did in response. In addition, the questionnaire asked respondents about their household composition (e.g. number of members, children, people with disability), dwelling characteristics (e.g. dwelling type, housing conditions), and economic circumstances (e.g. employment status), among other items. These items provide indicators we can leverage to unpack the correlates of energy insecurity. (More information on the survey sample and the measurement of variables is provided in the supplementary materials.)

### 3. Analysis and results

#### 3.1. Overall patterns of household energy insecurity

Figure 1 displays the percentage of respondents who reported that their household was unable to pay an energy bill during each of the 13 months covered by the survey (month 1 is May 2020, month 2 is June 2020, and so forth, with month 13 as May 2021) as well as those who received a shut-off notice from their utility provider and those who had their service disconnected due to nonpayment<sup>3</sup>. The apex for each of the three indicators was during the first month of measurement—May 2020—during which 12.8% (95% CI: [11.1%, 14.4%]) of respondents indicated that they could not pay an energy bill, 9.12% (95% CI: 7.65%, 10.6%]) reported that they received a shut-off notice, and 4.34% (95% CI: [3.20%, 5.48%]) reported having their service disconnected. Over the course of the subsequent 12 months, across the three indicators, there was a general decline and then a leveling out in the prevalence of household energy insecurity<sup>4</sup>.

These month-to-month estimates suggest that energy insecurity was at its highest in the early months of the pandemic. The timing of this hardship coincides with the most severe economic disruption resulting from the public health measures implemented to control the spread of COVID-19. The months of lower prevalence may relate to seasonality (i.e. households likely consume less energy during the temperate autumn and spring months, thereby reducing energy costs). Moreover, rates of energy insecurity were likely reduced due to changes in policy and

the availability of public financial assistance. Regarding policy, many governors and public utility commissions required utilities to suspend disconnections [40, 41]. These disconnection moratoria had different durations, and some unregulated utilities also temporarily suspended disconnections voluntarily. In addition, the U.S. Congress provided financial assistance through both direct recovery payments as well as increased funding for programs, such as the Low Income Home Energy Assistance Program (LIHEAP) and the Weatherization Assistance Program (WAP), which may have reduced energy-related material hardship. The data shown in figure 1, however, reveal that while these programs may have helped to reduce household energy insecurity, they did not eliminate it. The rates of energy insecurity, when extrapolated to the U.S. population of low-income households, suggest that millions of households and tens of millions of individuals experienced some form of energy insecurity during the first year of the COVID-19 pandemic.

Figure 2 displays the percentage of respondents who experienced each type of energy insecurity as a discrete event (i.e. during only a single month) as compared to the percentage that reported having experienced a form of energy insecurity on multiple occasions (i.e. during two or more months) over the course of the survey. These values provide an estimate of short-term and persistent events. It is evident that, across the three indicators, energy insecurity was a persistent condition for a substantial proportion of households.

As illustrated in figure 2, among those that could not pay an energy bill during the study period, 70% could not afford this bill in at least two months. In addition, a majority of the respondents who either received a shut-off notice or had their energy service disconnected experienced these events on at least two occasions. Moreover, as we examine directly below, these data raise the possibility that, once a household experiences any instance of energy insecurity, it is more likely that they experience it on an enduring basis. First, however, we turn to multivariate analysis to examine the correlates of the incidence and persistence of household energy insecurity.

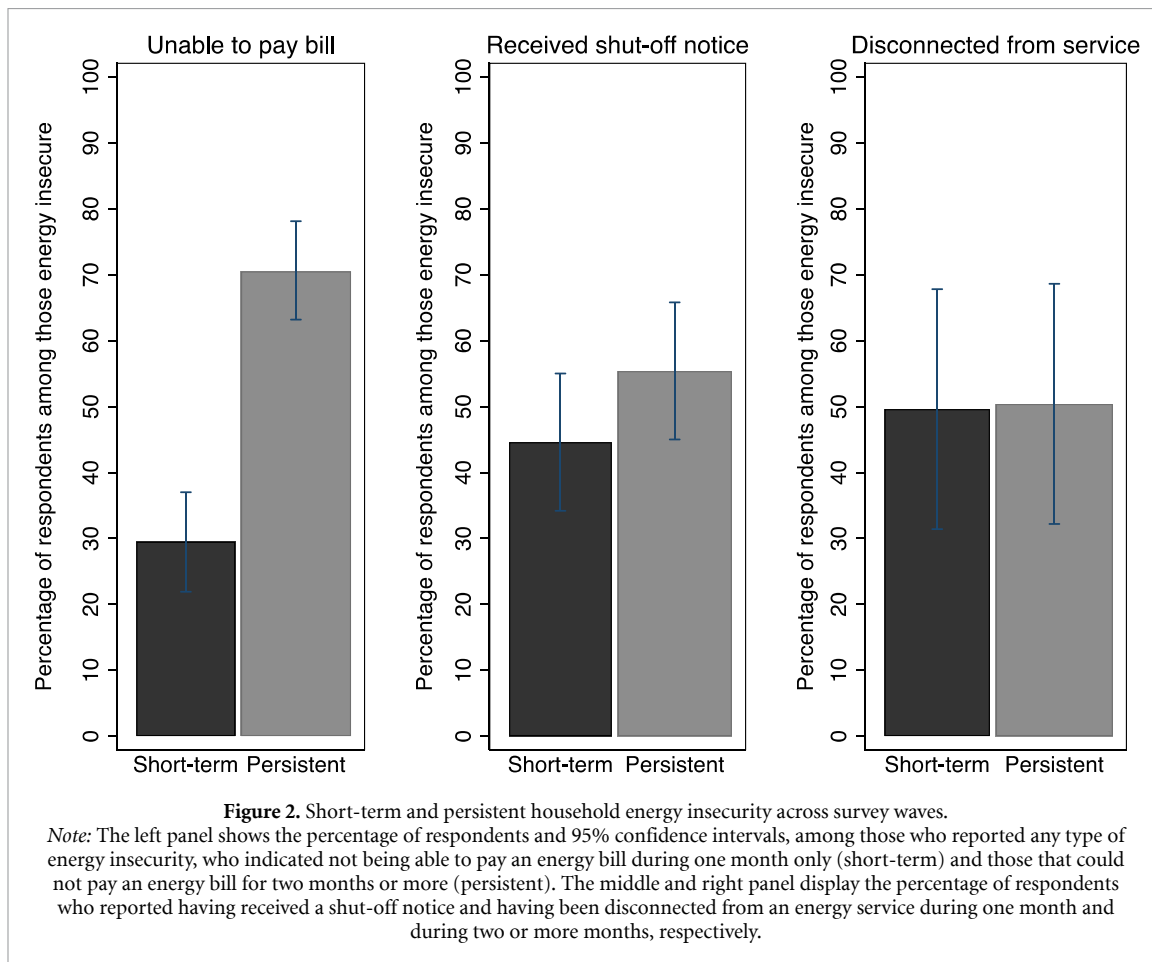
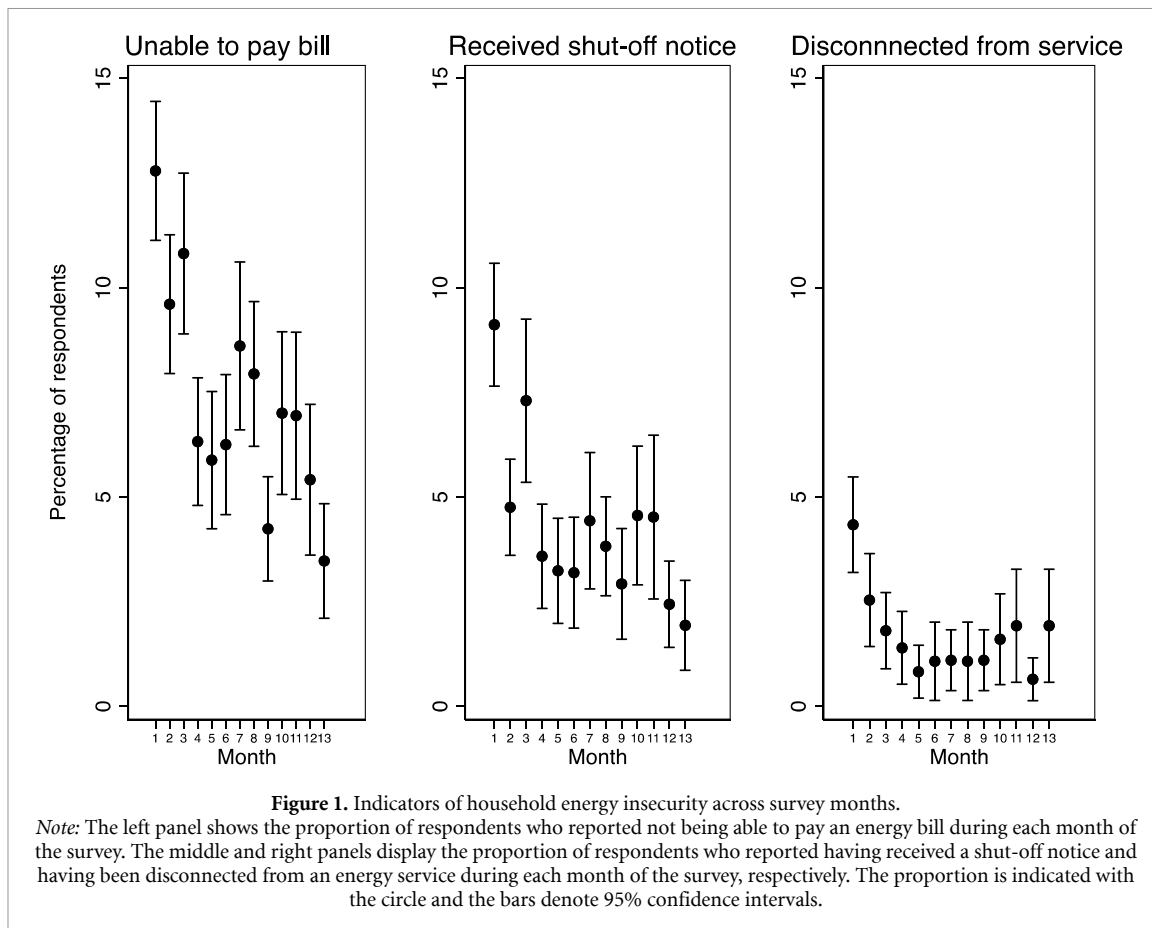
#### 3.2. Correlates of household energy insecurity

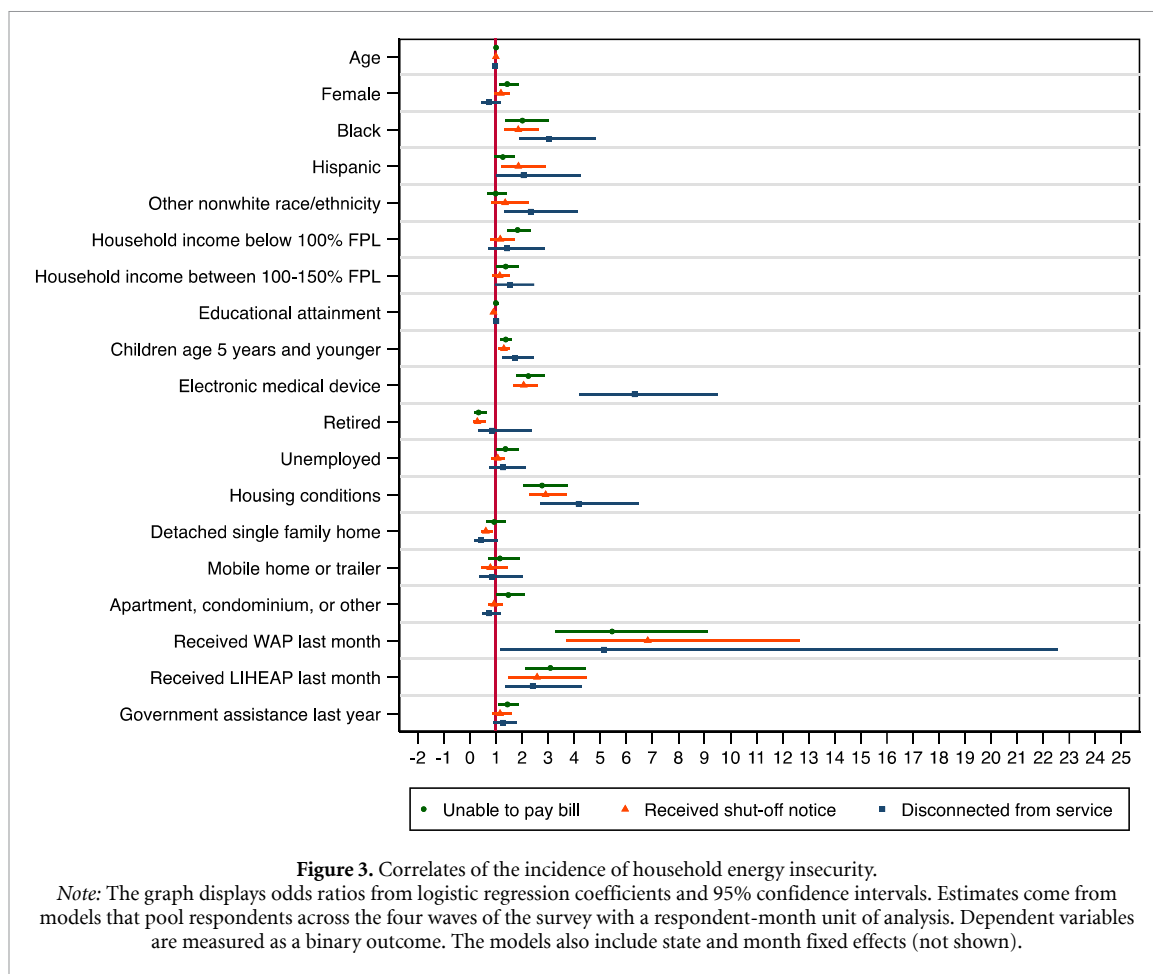
As a baseline analysis, we examine factors associated with any incidence of household energy insecurity. We use logistic regression to model household energy insecurity—separately using each of our three binary indicators—as a function of a suite of sociodemographic attributes, household characteristics (including both composition and physical dwelling conditions), and several contextual measures<sup>5</sup>. The regressors we include in the models are based on

<sup>3</sup> Our survey design assumes that respondents were able to correctly recall these outcomes. Although such recall questions may be prone to error, we think it is likely that respondents remember the timing of these extreme conditions and circumstances. Nonetheless, to address potential recall bias, we also analyzed the data on a wave-by-wave basis (see figure S1 in the supplementary materials).

<sup>4</sup> Figures S2–S5 in the supplementary materials reproduce the graphs in figure 1 separately across race and ethnicity, income categories, households with and without children, and households with and without at least one poor housing condition.

<sup>5</sup> The findings reported below are substantively similar when using a linear probability model specification (see table S3 in the supplementary materials).





past research [13, 15], identifying key factors that help explain variation in energy insecurity outcomes. In addition, the models include month and state fixed effects to capture unobserved factors within months and states.

The estimates displayed in figure 3 are odds ratios from models that pool respondents across all four waves of the survey with a respondent-month unit of analysis (see table S2 in the supplementary materials for results in tabular form)<sup>6</sup>. The estimates show several consistent sociodemographic correlates of household energy insecurity. Black and Hispanic respondents, compared to white respondents, were more likely to be unable to pay an energy bill, receive a shut-off notice, and be disconnected from their utility service altogether. In addition, respondents with lower incomes (the excluded category are respondents with incomes between 150%–200% FPL) were more likely to be unable to pay a bill, and the estimated odds ratios indicate these households were more likely to have had their service disconnected, though the confidence intervals include zero. Several other

sociodemographic variables also show statistically significant associations with the three measures of energy insecurity. Households with at least one child under the age of five and those with an individual who relies on an electronic medical device<sup>7</sup> were both more likely to experience energy insecurity during the first year of the COVID-19 pandemic, while retired respondents were less likely.

With respect to housing characteristics, respondents who described their dwellings as having at least one deficiency were more likely to report challenges in meeting their energy needs across all three indicators, even when controlling for dwelling type. In general, dwelling type was unrelated to energy insecurity, except for those who reside in apartments who were, all things equal, more likely to be unable to pay an energy bill. Finally, respondents who received government assistance in the year prior to the pandemic were more likely to be unable to pay an energy bill and respondents who received either LIHEAP or WAP in

<sup>6</sup> When estimating the same logistic regression models separately for each month, the results indicate similar patterns (see tables S4–S6 in the supplementary materials).

<sup>7</sup> Electronic medical devices include dialysis machines, drug-releasing pumps, and various diagnostic equipment, and, for the purposes of this study, represent households with a medically-vulnerable resident.



the last month were, on average, more likely to experience all forms of energy insecurity<sup>8</sup>.

To put these estimates in context, we use the pooled logistic regression estimates to compute predicted probabilities for each variable, holding the other variables at their mean values. For example, the predicted probability that a Black respondent reported being unable to pay an energy bill was twice as large as non-Black respondents, at 0.07 (95% CI: [0.05, 0.09]). The differences are similar in scale for the lowest income category (i.e. respondents with household incomes below 100% FPL), households with young children, someone relying on an electronic medical device, and respondents residing in dwellings with poor conditions. The difference in predicted probabilities for households receiving energy-related financial assistance are larger in magnitude. Respondents that received LIHEAP and WAP had predicted probabilities of 0.11 (95% CI: [0.06%, 0.15%]) and 0.18 (95% CI: [0.09%, 0.27%]), which was about three and six times higher, respectively, compared to respondents that did not receive these types of assistance. The differences in the estimated predicted probabilities are of similar magnitudes for these same variables with respect to the shut-off notice and disconnection outcomes.

### 3.3. Analysis of persistent energy insecurity

To analyze persistent household energy insecurity, we employ a couple of modeling strategies. First, we estimate an ordered logistic regression model that measures each energy insecurity indicator as three ordered outcomes: no reported energy insecurity, one-time energy insecurity, and multiple instances of energy insecurity (these measures are displayed in figure 2). In these models, we consider one-time energy insecurity as ‘short-term’ and multiple instances (i.e. two or more) as ‘persistent’<sup>9</sup>. Second, we re-estimate the baseline models described above, adding one-month lagged measures of energy insecurity. This approach leverages the longitudinal structure of the survey to explicitly capture the extent to which a household that recently experienced energy insecurity, does so again during the next month. In presenting results of these analyses, we also briefly note robustness checks that we performed that consider alternative models and measurements.

Figure 4 reports proportional odds ratios from ordered logistic regression models for each indicator of household energy insecurity (see table S7 in

the supplementary materials for results in tabular form)<sup>10</sup>. In general, these estimates are quite similar to those reported from the binary logistic models, which suggests that factors associated with any single instance of energy insecurity are comparable to those correlated with persistent energy insecurity. The estimates indicate that Black and Hispanic respondents, on average, were more likely to experience multiple instances of energy insecurity relative to white respondents (the excluded category) across each of the three indicators. Moreover, respondents residing in households with young children, someone relying on an electronic medical device, and in dwellings in poor physical condition were also more likely to experience difficulty paying energy bills or facing disconnections on multiple occasions during the course of the first year of the pandemic. And, again, respondents receiving energy financial assistance were also more likely to have experienced persistent forms of energy insecurity.

We can use these model estimates to generate predicted probabilities (i.e. average marginal effects) for different categories of the outcome variable, most importantly short-term and persistent energy insecurity. Table 1 displays these estimates for several variables. Two key patterns emerge. First, these variables help predict both short-term and persistent forms of household energy insecurity. For instance, a Black respondent—relative to a non-Black respondent, all else equal—was more likely to fall into both the short-term and the persistent energy insecure categories. This same pattern holds for most of the other displayed variables (not all of the predicted probabilities reach conventional levels of statistical significance, especially those involving disconnections which may reflect the relative infrequency of these outcomes). Second, the size of the effect is larger for all variables for the persistent outcome. That is, while a Black respondent, a household with a young child, or someone living in poor housing conditions was more likely to experience short-term energy insecurity, they were even more likely to experience it on multiple occasions throughout the pandemic relative to non-Blacks, households without children, and people living in better housing conditions, respectively, and this was the case across each of the three indicators.

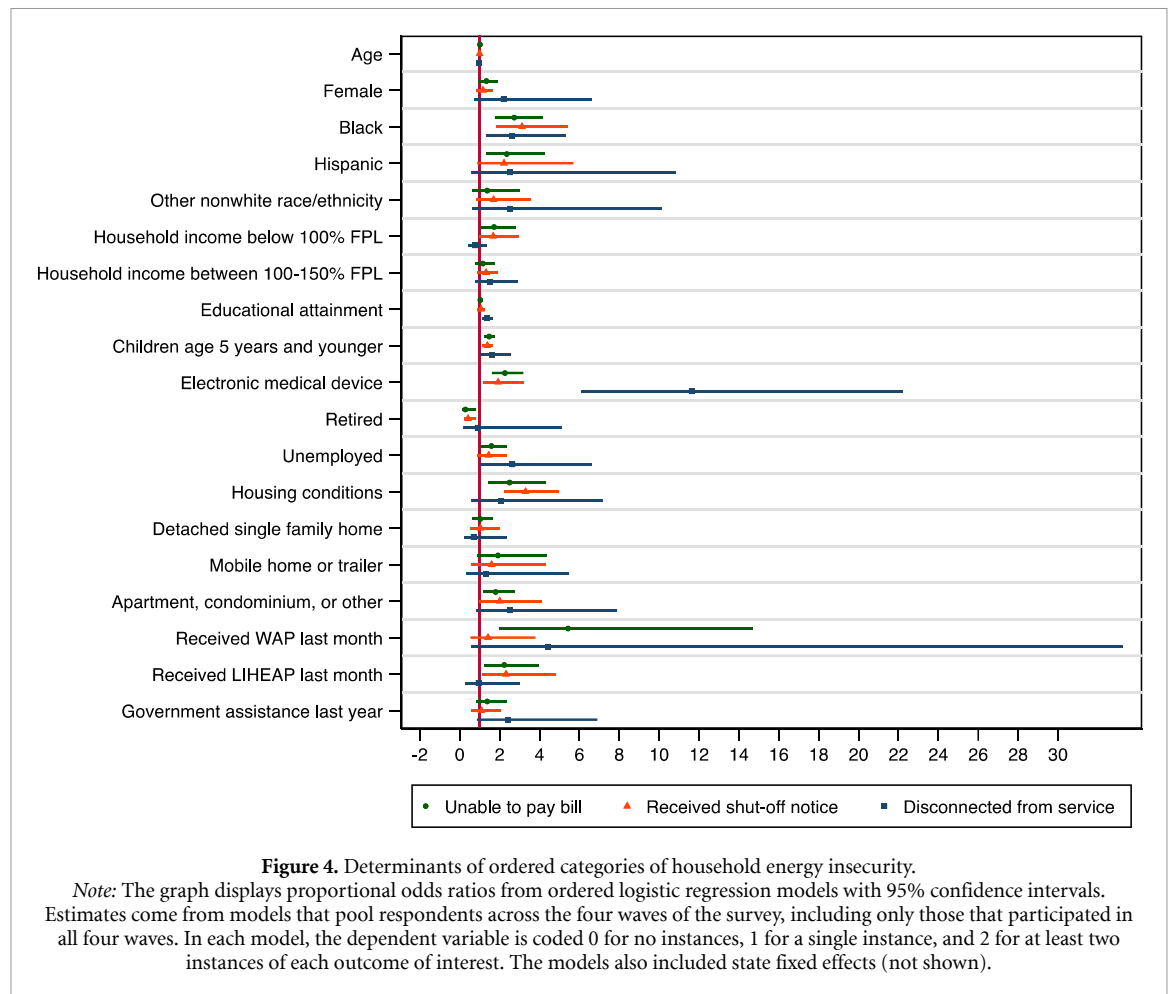
As a robustness check, we also estimated models that treat the number of months in which a respondent experienced each type of energy insecurity as a count outcome, which enables us to examine the factors associated with the number of instances a household experienced energy insecurity over the

<sup>8</sup> The number of respondents that report receiving LIHEAP and WAP assistance was low (means and standard deviations are 0.04 and 0.20 for LIHEAP and 0.01 and 0.07 for WAP), which is why there are wide 95% confidence intervals reported in figure 3.

<sup>9</sup> Moreover, we restrict the sample for these analyses to respondents that participated in every wave of the survey so we have data for each respondent for the full study period.

<sup>10</sup> We performed Brant tests [47] to examine the parallel regression assumption of ordered logistic models, and all results showed that this assumption is not violated.





**Table 1.** Predicted probabilities for select variables for short-term and persistent household energy insecurity outcomes.

	Unable to pay bill		Received shut-off notice		Disconnected from service	
	Short-term	Persistent	Short-term	Persistent	Short-term	Persistent
Black	.027**	.121**	.041**	.094**	.016*	.023
Hispanic	.022**	.094**	.029	.063	.013	.019
One child age 5 years or younger	.008	.032	.014	.027	.008	.010
Electronic medical device	.024**	.094**	.023**	.047*	.052**	.064**
Poor housing conditions	.026**	.090**	.045**	.080**	.011	.013
Received WAP last month	.034**	.217**	.017	.036	.026	.039

Note: The table displays predicted probabilities using the values of other variables as observed in the data, estimated from ordered logistic regression models. Significance levels: \*\*, .01, \*, .05.

first year of the pandemic. In addition, we estimated a model in which we conceptualized persistent energy insecurity as experiencing it any two or more successive months. In both cases the results are substantively similar to those reported above (see tables S8 and S9 in the supplementary materials for full results), and collectively suggest that the factors associated with any single occurrence of energy-related material hardship are also related to multiple occurrences, or a more persistent condition, of energy insecurity.

Our second main approach to investigating persistence is to modify the baseline logit models we estimated for the incidence of energy insecurity, by including one month lagged measures of energy

insecurity (the rest of the models are unchanged)<sup>11</sup>. The objective is to explicitly examine whether a household that experienced energy insecurity in the past month is more likely to experience it again during the next month. In these models we include a lagged measure for all three indicators, which also enables consideration of whether there is a progression of energy insecurity from more modest (inability to pay a bill) to more severe (disconnection from service).

<sup>11</sup> Estimating these models requires dropping the May 2020 (i.e. first wave) outcomes from the analysis, so the sample size for this exercise is reduced.

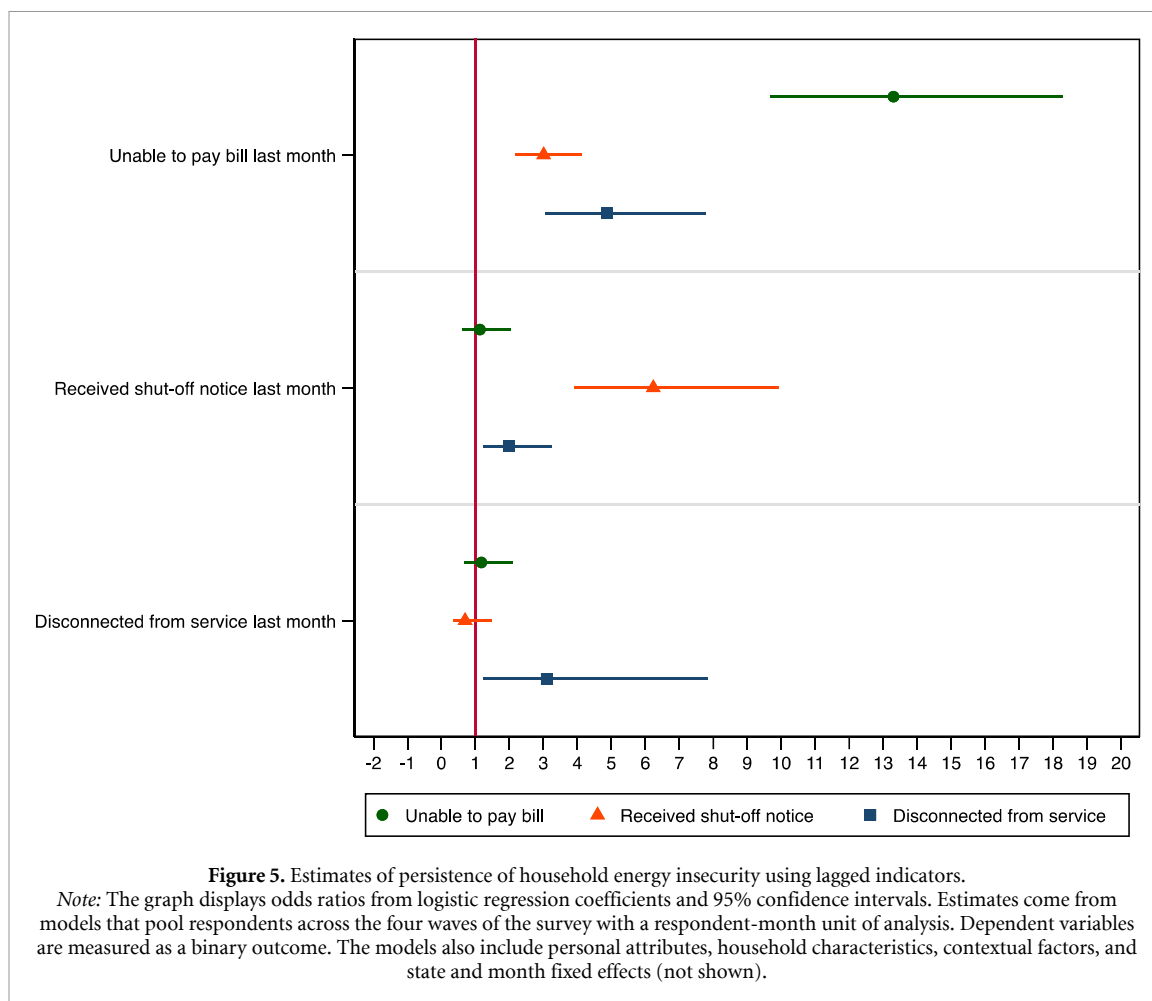


Figure 5 displays odds ratios for the lagged indicators (see table S10 in the supplementary materials for full results). The estimates show that respondents indicating an inability to pay an energy bill in the prior month, controlling for personal and household characteristics, is positively associated with each of the three energy insecurity indicators in the next month. There is similar evidence for households receiving a shut off notification or having their service disconnected altogether; the estimates suggest these outcomes in the previous month are positively correlated with similar experiences in the next month. As a robustness check, we also considered an alternative lagged measure which captured the respondent's previous experience in the last three months, with substantively similar results (see figure S6 in the supplementary materials). Collectively, therefore, these results suggest that energy insecurity is a persistent experience for many low-income households, with many experiencing the same type of energy insecurity in successive months.

#### 4. Discussion

The results of this study reaffirm previous findings that there are high levels of energy insecurity among low-income households in the United States, with

historically disadvantaged populations more likely to experience energy insecurity than other groups. Our analysis shows that these patterns were evident throughout the first year of the COVID-19 pandemic. We find important sociodemographic disparities: people of color, those in the lowest-income strata, households with children under the age of five, and people who rely on an electronic medical device were less likely to be able to pay an energy bill, more likely to receive a notice of disconnection, and more likely to have their energy service disconnected. In addition, people residing in dwellings with poor physical conditions were more likely to experience energy insecurity over the course of the pandemic. Finally, we find that people receiving energy-related financial assistance, through the federal LIHEAP and WAP programs, were also more likely to face challenges meeting their energy needs.

The longitudinal survey design is a key innovation of this study, enabling us to contribute an important temporal component to the extant literature. Specifically, we can measure the persistent, or cyclical, nature of energy insecurity, which is not possible through cross-sectional studies. Descriptively, we find, of those households that experienced energy insecurity during the first year of the pandemic, most experienced it on a repeated basis. In

fact, many households experienced energy insecurity in successive months, suggesting that it is difficult for households to extricate themselves from this type of material hardship once it begins. Moreover, we find that Black respondents, households with young children, and households in poor physical condition, were even more likely to experience persistent energy insecurity over the course of the first year of the pandemic. Therefore, the disparities that past research has shown to explain spatial patterns of household energy insecurity, are also helpful for understanding temporal patterns.

The findings of this study focus on the prevalence and correlates of energy insecurity among low-income U.S. households during the first year of the COVID-19 pandemic. For this reason, it is difficult to say if the observed incidence of energy insecurity during this time—short-term or persistent—is different from what might have occurred in the absence of the pandemic. Moreover, without frequent, longitudinal data sources capturing the prevalence of energy insecurity, it is impossible to construct meaningful trends, which is something that future research might address, especially in light of concerns that climate change may create additional burdens [42]. However, the correlates of energy insecurity presented here are consistent with existing studies that rely on other data types from other time periods, which suggests that the individual and household characteristics associated with energy insecurity were not specific to the COVID pandemic.

A further limitation of the analysis is that it does not directly address the effects of insecurity on individual and household well-being. There are several things to note here. First, the emphasis in this study on persistence should not diminish the potential severe effects of short-term energy insecurity. Challenges paying for basic energy services can result in difficult trade-offs for families, including choices about whether to ‘heat or eat’ or whether to forgo necessary health services to meet utility expenses [43]. Moreover, a single utility shut-off can have severe consequences for households, forcing them to substitute utility-provided energy services with dangerous alternatives, such as using electrical space heaters or kitchen stoves as heating sources [16, 44, 45]. Lastly, the three measures of energy insecurity employed in this study may obscure more subtle forms. For example, although people may be able to meet their energy-related financial obligations (i.e. pay monthly bills to avoid service termination), they may limit their energy consumption in the process [46], which could lead individuals and families to live in uncomfortable and potentially dangerous temperatures.

In the United States, the historical policy response to household energy insecurity has been the provision of targeted, federal financial assistance, like LIHEAP

and WAP. LIHEAP is intended to provide eligible households with bill assistance or emergency funds to help mitigate delinquency on utility payments; whereas, WAP is designed to help improve the energy efficiency of low-income housing stock and reduce overall financial energy burdens. Over the course of the pandemic, Congress infused these programs with additional resources as part of recovery packages in the anticipation that the economic disruption would increase demand for these resources. The analysis here, however, found that people receiving assistance from these programs were more, not less, likely to experience energy insecurity<sup>12</sup>. These findings may suggest that the additional funding appropriated by the federal government was too late to reduce energy insecurity for low-income families. In the case of LIHEAP, the program only provides assistance once a year to an eligible household and temporary relief may have been insufficient for people experiencing a cycle of persistent energy insecurity. Moreover, programs such as WAP are intended to provide long-term benefits through energy efficiency investments, but they may not provide immediate relief to energy insecure households. In the context of this study, therefore, recent receipt of LIHEAP and WAP may serve as both indicators of households struggling with energy insecurity as well as households that have successfully accessed resources to mitigate it.

Although the evidence here does not suggest that federal efforts to reduce energy insecurity during the pandemic through the LIHEAP and WAP programs were effective, there were other initiatives that may have lowered overall rates of both short-term and persistent energy insecurity. For example, during the study period, Congress provided enhanced unemployment insurance, direct financial assistance to most Americans, and tax credit payments to families with children. In addition, at the state level, many governors and public utility commissions imposed moratoria on utility disconnections, which prevented households from losing their service due to non-payment. It is reasonable to assume that, absent these policies, the high rates of energy insecurity among low-income households found in this study would have been even higher. In this sense, given

<sup>12</sup> One possible explanation for these findings is that respondents had difficulty pinpointing the exact month that they received WAP assistance, which would affect the correlation with the measures of energy insecurity. To examine this possibility, we replicated our analysis (not shown) using a different measure of WAP assistance—whether or not a respondent indicated receiving WAP assistance at any point during the year prior to Wave 1 of the survey, which leans less heavily on a respondent identifying a precise month. This analysis produces similar results, as does an analysis that similarly measures past LIHEAP assistance (not shown), which provides reassurance that these results are not an artifact of survey measurement.

the unprecedented efforts to alleviate financial hardships during the pandemic, the remaining prevalence of and disparities in energy insecurity are reasons for concern.

The policy implications of this study, however, run deeper. In this analysis, we found that households who experience energy insecurity are likely to struggle with it on a recurring basis. Recognizing energy insecurity as a persistent problem requires both shifting a common perspective that this material hardship is a short-term issue precipitated by acute events, like severe weather events or economic shocks (e.g. gas price spikes or layoffs), and rethinking policy solutions that recognize the recurrent nature of the problem. For example, solutions like LIHEAP, which offer eligible households bill assistance once a year, are not sufficient to address energy insecurity. Rather, programs that provide longer-term and more systemic and preventative assistance, such as WAP, should be adequately funded and extended in eligibility. Expanding programs like WAP is more likely to mitigate the persistent nature of energy insecurity revealed in this analysis by directly concentrating on a determinant of energy insecurity that continuously appears in the literature, the low-income community's housing stock. Additionally, programs that promote ownership of residential solar and new affordable and energy efficient housing designs, may also help energy insecure households break the cycle of material hardship. However, expanding resources and eligibility for programs like WAP and helping households gain access to new technologies is not a fail-safe. Importantly, they do not address accumulated utility debts which make it difficult for people to pay bills and avoid disconnections. For this reason, effective policy also will likely require that governments partner with utility companies to design creative payment programs and debt forgiveness efforts that can address not just arrears in a static state, but take a long-term, dynamic approach to helping households break out of persistent energy insecurity.

Addressing this problem comprehensively further necessitates that scholars and researchers have access to better information about energy insecurity, including data on the location of utility disconnections, so that practitioners and policymakers can target their efforts accordingly. For their part, scholars can contribute to this effort by continuing to measure the prevalence and correlates of household energy insecurity, preferably through longitudinal surveys that, as shown here, provide unique analytical leverage to understand the spatiotemporal dimensions of energy insecurity.

### Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: <https://doi.org/10.7910/DVN/3D5LIQ>.

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### Conflict of interests

The authors declare no competing financial or non-financial interests.

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### Human subjects

This study was approved by the Indiana University Human Subjects & Institutional Review Board as exempt status.

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### References

- [1] Mutikani L 2021 US economy contracted 19.2% during COVID-19 pandemic recession *Reuters* 29 July
- [2] Bureau of Labor Statistics (BLS) 2021 Unemployment rises in 2020, as the country battles the COVID-19 pandemic
- [3] Heflin C, London A S and Scott E K 2011 Mitigating material hardship: the strategies low-income families employ to reduce the consequences of poverty *Sociol. Inq.* **81** 223–46
- [4] Desmond M 2016 *Evicted: Poverty and Profit in the American City* (New York: Broadway Books)
- [5] Gundersen C and Ziliak J P 2015 Food insecurity and health outcomes *Health Aff.* **34** 1830–9
- [6] Gama E 2016 Health insecurity and social protection: pathways, gaps, and their implications on health outcomes and poverty *Int. J. Health Policy Manage.* **5** 183
- [7] Heflin C, Sandberg J and Rafail P 2009 The structure of material hardship in US households: an examination of the coherence behind common measures of well-being *Soc. Probl.* **56** 746–64
- [8] Bednar D J and Reames T G 2020 Recognition of and response to energy poverty in the United States *Nat. Energy* **5** 432–9
- [9] Brown M A, Soni A, Lapsa M V, Southworth K and Cox M 2020 High energy burden and low-income energy affordability: conclusions from a literature review *Prog. Energy* **2** 042003
- [10] Bohr J and McCreery A C 2020 Do energy burdens contribute to economic poverty in the United States? A panel analysis *Soc. Forces* **99** 155–77
- [11] Hernández D 2016 Understanding 'energy insecurity' and why it matters to health *Soc. Sci. Med.* **167** 1–10

- [12] Steele A J H and Bergstrom J C 2021 “Brr! It’s cold in here” measures of household energy insecurity for the United States *Energy Res. Soc. Sci.* **72** 101863
- [13] Graff M, Carley S, Konisky D M and Memmott T 2021 Which households are energy insecure? An empirical analysis of race, housing conditions, and energy burdens in the United States *Energy Res. Soc. Sci.* **79** 102144
- [14] Hernández D and Laird J 2021 Surviving a shut-off: US households at greatest risk of utility disconnections and how they cope *Am. Behav. Sci.* **66**
- [15] Memmott T, Carley S, Graff M and Konisky D M 2021 Sociodemographic disparities in energy insecurity among low-income households before and during the COVID-19 pandemic *Nat. Energy* **6** 186–93
- [16] Campbell R B 2016 *Home Fires Involving Heating Equipment* (Quincy, Massachusetts: National Fire Protection Association)
- [17] Hernández D and Siegel E 2019 Energy insecurity and its ill health effects: a community perspective on the energy-health nexus in New York City *Energy Res. Soc. Sci.* **47** 78–83
- [18] Huang Y, Heflin C M and Validova A 2021 Material hardship, perceived stress, and health in early adulthood *Ann. Epidemiol.* **53** 69–75
- [19] Liddell C and Morris C 2010 Fuel poverty and human health: a review of recent evidence *Energy Policy* **38** 2987–97
- [20] Zhang Z, Shu H, Yi H and Wang X 2021 Household multidimensional energy poverty and its impacts on physical and mental health *Energy Policy* **156** 112381
- [21] Graff M and Carley S 2020 COVID-19 assistance needs to target energy insecurity *Nat. Energy* **5** 352–4
- [22] Lou J, Qiu Y L, Ku A L, Nock D and Xing B 2021 Inequitable and heterogeneous impacts on electricity consumption from COVID-19 mitigation measures *iScience* **24** 103231
- [23] Dreihobl A, Ross L and Ayala R 2020 *How High are Household Energy Burdens?* (Washington, DC: American Council for an Energy-Efficient Economy)
- [24] Finnigan R and Meagher K D 2019 Past due: combinations of utility and housing hardship in the United States *Sociol. Perspect.* **62** 96–119
- [25] Tach L M and Greene S S 2014 “Robbing Peter to pay Paul”: Economic and cultural explanations for how lower-income families manage debt *Soc. Probl.* **61** 1–21
- [26] Ku A L, Qiu Y L, Lou J, Nock D and Xing B 2022 Changes in hourly electricity consumption under COVID mandates: a glance to future hourly residential power consumption pattern with remote work in Arizona *Appl. Energy* **310** 118539
- [27] Best R, Burke P J and Nishitatenno S 2021 Factors affecting renters’ electricity use: more than split incentives *Energy J.* **42**
- [28] Best R and Sinha K 2021 Fuel poverty policy: go big or go home insulation *Energy Econ.* **97** 105195
- [29] Mohr T M 2018 Fuel poverty in the US: evidence using the 2009 residential energy consumption survey *Energy Econ.* **74** 360–9
- [30] Reames T G 2016 Targeting energy justice: exploring spatial, racial/ethnic and socioeconomic disparities in urban residential heating energy efficiency *Energy Policy* **97** 549–58
- [31] Hernández D, Jiang Y, Carrión D, Phillips D and Aratani Y 2016 Housing hardship and energy insecurity among native-born and immigrant low-income families with children in the United States *J. Child. Poverty* **22** 77–92
- [32] Lyubich E 2020 The race gap in residential energy expenditures *Energy Institute at Haas*
- [33] Best R 2022 Energy inequity variation across contexts *Appl. Energy* **309** 118451
- [34] Dreihobl A and Ross L 2016 *Lifting the High Energy Burden in America’s Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities* (Washington, DC: American Council for an Energy Efficient Economy)
- [35] Dogan E, Madaleno M, Inglesi-Lotz R and Taskin D 2022 Race and energy poverty: evidence from African-American households *Energy Econ.* **108** 105908
- [36] Heflin C M 2006 Dynamics of material hardship in the women’s employment study *Soc. Serv. Rev.* **80** 377–97
- [37] Heflin C 2016 Family instability and material hardship: results from the 2008 survey of income and program participation *J. Fam. Econ. Issues* **37** 359–72
- [38] Heflin C and Patnaik H 2022 Material hardship and the living arrangements of older Americans *J. Fam. Econ. Issues* **1–18**
- [39] Health and Human Services (HHS) 2020 *Annual Update of HHS Poverty Guidelines* (Federal Register)
- [40] Baker S H, Carley S and Konisky D M 2021 Energy insecurity and the urgent need for utility disconnection protections *Energy Policy* **159** 112663
- [41] Jowers K, Timmins C, Bhavsar N, Hu Q and Marshall J 2021 *Housing Precarity & the Covid-19 Pandemic: Impacts of Utility Disconnection and Eviction Moratoria on Infections and Deaths across US Counties* No. W28394 (Cambridge, MA: National Bureau of Economic Research)
- [42] Graff M, Konisky D M, Carley S and Memmott T 2022 Climate change and energy insecurity: a growing need for policy intervention *Environ. Justice* **15** 76–82
- [43] Bhattacharya J, DeLeire T, Haider S and Currie J 2003 Heat or eat? Cold-weather shocks and nutrition in poor American families *Am. J. Public Health* **93** 1149–54
- [44] Hernández D 2018 What ‘Merle’ taught me about energy insecurity and health *Health Aff.* **37** 504–7
- [45] Harrison C and Popke J 2011 “Because you got to have heat”: the networked assemblage of energy poverty in eastern North Carolina *Ann. Am. Assoc. Geogr.* **101** 949–61
- [46] Cong S, Nock D, Qiu Y L and Xing B 2022 Unveiling hidden energy poverty using the energy equity gap *Nat. Commun.* **13** 1–12
- [47] Brant R 1990 Assessing proportionality in the proportional odds model for ordinal logistic regression *Biometrics* **46** 1171–8