nature communications

Article

https://doi.org/10.1038/s41467-024-53913-y

Assessing demographic vulnerability and weather impacts on utility disconnections in California

Received: 17 April 2024

Accepted: 25 October 2024

Published online: 05 November 2024

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When a household is disconnected from their electric utility service the consequences can be severe, including accumulation of debt, the inability to maintain comfortable temperatures, and in the most extreme cases, homelessness or mortality. While the survey-based literature on utility disconnections has yielded important findings about which households are most likely to experience a utility shutoff, only a few existing studies have used data from utility companies themselves. In this analysis, we utilize zip-code level data from four of California's largest utility providers to measure socio-demographic disparities in disconnections, in addition to the impact of adverse weather. We find that zip codes with a higher share of vulnerable households, especially Black and Hispanic households and households with young children, face a higher number and rate of utility disconnections, even after controlling for an extensive set of factors that are commonly thought to explain higher rates of energy insecurity, including income, housing characteristics, and energy costs. Our analysis also suggests that socio-demographic and weather disparities in disconnections differ between utility types. We conclude by discussing the implications of the findings for research and policy, including the impact of regulation, utility provider practices, and more extreme weather driven by climate change.

When a household is disconnected from their energy utility service they can experience severe consequences, including accumulating debt[1], engaging in risky behavior to mitigate exposure to dangerous temperatures[2], and in extreme cases homelessness[3] or mortality[4]. Recent studies suggest that disconnections from electricity and natural gas service are common in the United States[5,6], and only partially mitigated by seasonal moratoria and other public policies designed to protect vulnerable households from losing access to vital energy services in their homes[7].

Extant literature has yielded important findings about who is most vulnerable to utility disconnections. Specifically, Black households, Hispanic households, low-income households, renters, people living with poor or inefficient housing conditions, those with medical conditions, and those with children in the home all face a higher likelihood of being shut off by their utility provider[5,6,8,9]. These studies rely on self-reported information collected through surveys. While survey-based techniques are valuable for measuring the prevalence and identifying the correlates of energy insecurity, surveys require respondents to report the incidence and timing of utility disconnections, which may be subject to recall bias. In addition, households most likely to experience utility disconnections may not be well-represented in the types of national surveys often employed in these studies, such as the U.S. Energy Information Administration's (EIA) Residential Energy Consumption Survey, or in surveys that require internet access to complete.

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Few existing studies analyze data on the number of utility disconnections as reported by the utilities themselves. A main reason is that there is generally a paucity of such data due to inconsistent, and in many places nonexistent, reporting requirements across the United States. At the present time, there is no national requirement that utility companies disclose this type of information. For example, information on customer disconnections for nonpayment are not included in standard utility data reports to agencies such as the EIA. Policies that exist at the state level vary widely, from mandatory reporting requirements to voluntary to none. During the initial year of the COVID-19 pandemic, many states required disclosure of historical and contemporary disconnections as part of moratoria policy, but these requirements have expired in the vast majority of places.

A couple of studies provide notable exceptions. Cicala[10] analyzes data from the two largest investor-owned electric utility companies in Illinois—Commonwealth Edison (ComEd) and Ameren—to measure racial disparities in utility disconnections and deferred payments. He finds that households in majority Black and Hispanic zip codes are more likely to be on deferred payment plans, participate in low-income energy assistance programs, and be disconnected from their utility service. Barreca et al.[11] use data from Southern California (SoCal) Edison to estimate the increase in electricity costs driven by higher temperatures, which contributes to higher rates of utility disconnection. They find that each additional day of extreme heat increases energy prices and thus the risk of a household having their utility service shut off.

In this article, we advance the extant literature in several ways. First, we use California utility data to examine whether Cicala's finding of zip-code level demographic disparities in Illinois' disconnections holds in another state where different utilities operate. Given the nascency of research in this area, establishing the presence of disparities in additional contexts is itself an important endeavor. Studying California in particular is important given the size of its population and economy. Second, our statistical analysis includes a broader set of variables than employed in past work, which enables a better estimation for the presence and magnitude of any disparities. Specifically, our models include measures of energy costs and housing characteristics[5,8], which allows us to more definitively rule out alternative hypotheses that underlie the previous finding of racial disparities. Third, our analysis across four utilities allows us to make some tentative inferences about how utility type may be associated with levels and rates of utility disconnection. Finally, and relatedly, analyzing data from utilities operating across the state of California allows us to gain further insight into how weather may impact utility disconnections in different climatic conditions.

We use utility disconnections compiled from monthly, zip-code level data from three of the largest investor-owned electric utilities in the state of California—Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and SoCal Edison—as well as from the Los Angeles Department of Water and Power (LADWP), a municipal provider. Collectively, these four utilities cover most of California geographically and serve nearly 26 million electric customers[12]. Disconnection data cover 2018, 2019, and the early months of 2020, before the COVID-19 pandemic led the California Public Utilities Commission to place a moratorium on disconnections for regulated utilities and LADWP self-imposed a similar moratorium. We combine these utility disconnections data with information on factors that may explain rates and distribution of utility shutoffs, including data from the U.S. Census Bureau's American Community Survey (ACS) on household demographics and housing characteristics, weather data from the Oregon State PRISM Climate Data, and measures of energy burden and energy costs from the Department of Energy's Low-Income Energy Affordability Data (LEAD) Tool.

Our results reveal that, even after controlling for factors that are commonly thought to explain higher incidence of energy insecurity, vulnerable demographic groups, namely, Black and Hispanic households and those with young children in the home, face a significantly higher likelihood of being disconnected. Specifically, zip codes with a more Black and Hispanic households are associated with larger overall numbers of disconnections and higher disconnection rates across all four utilities. Further we find that, overall, disconnections increase when monthly average temperatures are colder. However, utility-level analysis reveals that this effect is driven by PG&E, which covers most households in northern and central California. Among households concentrated in southern California—those covered by LADWP SoCal Edison, and SDG&E—disconnections are driven by hotter temperatures. There are also substantial sociodemographic disparities in disconnections among utilities, with suggestive evidence that utility disconnections are more frequent in areas served by investor-owned utilities compared to a municipal provider.

These results make important contributions to our understanding of energy insecurity in the United States. Notably, significant racial disparities in disconnections persist even after controlling for energy burden, in the form of energy costs and income, and poor housing conditions, which has been found previously to drive up the cost of a household's energy bill[13]. Our findings provide strong evidence that there is something unique about race and ethnicity that contributes to higher disconnection rates. Additionally, as temperatures continue to become more extreme due to climate change, our results suggest that disconnections will increase. This has substantial implications for both scholarship on the impacts of climate change and for policymakers that seek policies and programs to effectively mitigate or prevent utility disconnections.

Results

Table 1 presents summary statistics on the number of monthly zip code observations, the mean number of monthly disconnections, and the mean monthly disconnection rate for each utility in the dataset. Figure 1 presents the mean number of disconnections across the zip codes within each utility's service territory by year (left panel) and by month (right panel). Across the 3 years of data, among the IOUs, SoCal Edison had the highest number of average monthly disconnections at ~72 per month, followed by SDG&E (about 34) and PG&E (about 29). LADWP had the lowest number of mean monthly disconnections, averaging 16 disconnections per month across the study period. SDG&E and LADWP disconnections were more consistent across

Table 1 | Utility disconnections for California utilities, summary statistics

	Observations	Mean monthly disconnection rate (per 1000 households per zip code)	Mean monthly disconnections (per zip code)	SD	Min	Max
PG&E	13,021	4.53	29.01	77.43	0	605
SoCal Edison	9287	7.59	71.65	43.76	0	716
SDG&E	1727	3.39	34.48	27.39	0	153
LADWP	28,458	1.44	16.14	16.30	0	106

The mean monthly disconnection rate per 1000 households (Column 2) and total disconnections (Column 3) for the four California utilities in our dataset.

 https://doi.org/10.1038/s41467-024-53913-y

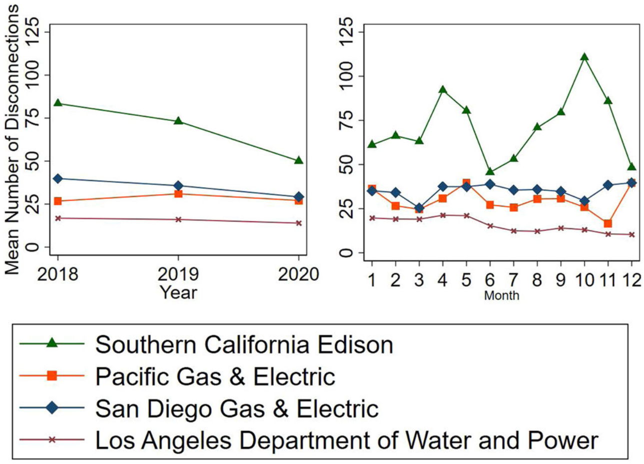

Fig. 1 | Trends in utility disconnections for California utilities. The number of total monthly disconnections in each year (left panel) and averaged in each month of the year (right panel) for the four California utilities in our dataset, PG&E (n = 13,021), SoCal Edison (n = 9287), SDG&E (n = 1727), and LADWP (n = 28,458).

months, with a maximum number of disconnections of 153 and 106, respectively. Comparatively, PG&E and SoCal Edison disconnected 605 and 716 households in their peak month. There are also notable disparities in the disconnection rate per 1000 households. SoCal Edison had a disconnection rate per 1000 households of 7.59, more than five times higher than LADWP's rate of 1.44. PG&E and SDG&E had a rate of 4.53 and 3.39, respectively.

To identify the correlates of utility disconnections, we estimate an ordinary least squares (OLS) regression model, separately using two outcome measures. First, we regress total disconnections, measured by zip code in each month of the study period, on a set of sociodemographic measures, energy costs, and housing characteristics. Second, we estimate the same model using the disconnection rate in each zip code (calculated on a per 1000 customer basis for ease of interpretation). The rate of disconnection allows for a direct measure of disconnection risk.

The demographic variables of primary interest are the share of the population that are Black and Hispanic households, measured as proportions for each zip code within the service territories of the utilities, as well as the share of the population with young children in the home. To analyze the effect of weather, we use the monthly average temperature in our primary model, again at the zip code level. The analysis also controls for other factors that past research on the correlates of energy have found to be associated with variation in utility disconnections, including other sociodemographic characteristics (age, income), housing characteristics (renters, total households), housing conditions (age and size), and energy costs. To account for other factors that may influence utility disconnections, we include a measure of utility disconnection protections, measured as the days in each month that the state of California prohibited utilities from shutting off customers, and a series of fixed effects that control for unobserved time, geographic, and utility-level variation. In Supplementary Table S1, we further incorporate a fixed effect that interacts month and utility, which helps to control for unobserved heterogeneity in seasonal utility behavior, such as discrepancies in disconnection decisions during weather extremes. Results confirm that our main findings hold.

We present our main results in Table 2. The model estimates show that race and ethnicity are positively associated with utility disconnections (see Column 1). More specifically, the coefficients suggest that a 1% increase in the Black (Hispanic) share of the population of a zip code corresponds to about 0.36 (0.21) more disconnections in that zip code in each month. Extrapolating from these estimates, for a 10%

Table 2 | Determinants of the total number of utility disconnections and disconnection rate

	Total disconnections	Disconnection rate (per 1000 households)
Black population percent	0.361***	0.020***
	(0.016)	(0.001)
Hispanic population percent	0.207***	0.009***
	(0.010)	(0.001)
Percent of children under 5	1.505***	0.092***
	(0.097)	(0.009)
Over 65%	−0.048	−0.034***
	(0.032)	(0.003)
Median income per $1000	−0.079***	−0.016***
	(0.008)	(0.001)
Renter percent	−0.154***	−0.013***
	(0.010)	(0.001)
Total households per 1000	2.997***	
	(0.029)	
Energy costs per $1000	1.183*	0.342***
	(0.367)	(0.034)
Monthly average temperature	−0.356***	−0.037***
	(0.072)	(0.007)
Protected days	−0.994***	−0.107***
	(0.054)	(0.005)
PG&E	33.859***	3.085***
	(0.524)	(0.047)
SoCal Edison	65.926***	6.442***
	(0.525)	(0.048)
SDG&E	26.448***	2.782***
	(0.942)	(0.086)
Detached single-family %	2.823	−0.356*
	(2.093)	(0.192)
Attached single-family %	2.042	−0.452**
	(2.093)	(0.192)
2 apartments	2.774	−0.369*
	(2.098)	(0.192)
3–4 apartments	3.696*	−0.341
	(2.095)	(0.192)
5–9 apartments	2.298	−0.398**
	(2.092)	(0.192)
10 or more apartments	2.900	−0.353*
	(2.093)	(0.192)
Mobile home or other	2.812	−0.273
	(2.093)	(0.192)
House built since 2014 %	0.466***	−0.004
	(0.070)	(0.006)
House built 2010–2013 %	0.653***	0.015***
	(0.057)	(0.005)
House built 2000–2009 %	0.488***	0.009
	(0.059)	(0.005)
House built 1980–1999 %	0.495***	0.002
	(0.054)	(0.005)
House built 1960–1979 %	0.271***	−0.020***
	(0.055)	(0.005)
House built 1940–1959 %	0.253***	−0.002
	(0.053)	(0.005)

Table 2 (continued) | Determinants of the total number of utility disconnections and disconnection rate

	Total disconnections	Disconnection rate (per 1000 households)
House built before 1939 %	0.156***	−0.007
	(0.055)	(0.005)
1 room house	0.548***	0.047**
	(0.207)	(0.019)
2–3 room house	0.464**	0.061***
	(0.213)	(0.020)
4–5 room house	0.649***	0.088***
	(0.212)	(0.019)
6–7 room house	0.706***	0.051***
	(0.215)	(0.020)
8 or more room house	0.712***	0.068***
	(0.211)	(0.019)
Month FE?	Yes	Yes
Year FE?	Yes	Yes
Utility FE?	Yes	Yes
Observations	51,710	51,710
R^2	0.453	0.456

Cells contain OLS coefficients, with robust standard errors in parentheses. Two-sided tests were used for all analyses.
Levels of statistical significance are denoted by p values as follows: $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

increase in the share of Black and Hispanic households in a given zip code, we would expect to see about 43 and 25 more disconnections over the course of a year, on average.

The model estimates for disconnection rates show similar patterns (see Column 2). For every 1000 households, disconnection risk increases by 0.59% and 0.26% for a 1% increase in the share of Black and Hispanic households, respectively. Importantly, these increases account for an extensive list of factors that the extant literature has found to be associated with disconnections, such as income, housing characteristics and conditions, and energy costs, which suggests that there is something unique about race and ethnicity separate from income and these other factors that drives disconnections.

To further test why racial disparities persist even after accounting for factors we would expect to drive utility disconnections, we include several additional models in the Supplementary Information. The first addresses the possibility that our findings are at least partially driven by geography and race, where electricity distribution may vary in a way that is correlated with race. Supplementary Table S2 includes a fixed effect at the county level to account for potential, time-invariant unobserved differences between counties that may impact the likelihood that a household is disconnected. Racial disparities do not decrease with the inclusion of county fixed effects, but instead increase. The second model examines the relationship between race and income by including interaction terms between the percentage of Black and Hispanic households of a zip code, respectively, and median income. Supplementary Table S3 shows a small but statistically significant positive coefficient on the interaction between Black percent and median income, suggesting that zip codes with more Black households are more likely to be disconnected even as their income increases, which may explain some of the disparity in disconnections. The interaction between Hispanic percent and income is negative, conversely, suggesting that Hispanic households are disconnected less as their incomes rise.

We run an additional interaction model with race and variables we expect might mediate the relationship with disconnections. Supplementary Table S4 interacts race with the percentage of single-family homes and the percentage of renters in a zip code. This model serves as a more direct proxy of housing conditions for Black and Hispanic households. Results show that zip codes with both Black and Hispanic households are slightly less likely to be disconnected in zip codes with more single-family housing and more likely to be disconnected in zip codes with a higher number of renters. However, it should be noted that these effects are quite small and do not explain a substantial amount of variation in disconnections. The final model that we run to further attempt to explain racial disparities, found in Table S5, runs our primary set of regressors on a subsample of the zip codes that are majority–minority (i.e., where the percentage of the population is <50% White). This model shows that the housing variables have stronger effect sizes than in our main model (Table 2). However, even after controlling for these factors, racial disparities in disconnections are considerably more pronounced in majority–minority neighborhoods when compared to the full sample.

We also find that monthly average temperature is associated with an increase in the number and rate of disconnections. Specifically, a 1° decrease in the monthly average temperature (measured in Celsius) corresponds to an additional 0.36 disconnections per month, or about 4.3 disconnections per year. To address concerns about serial correlation in the relationship between utility disconnections and weather in past months, the model in Supplementary Table S6 includes 1- and 2-month mean temperature lags. These lags are not statistically significant, nor do they mitigate the effect of temperature in the current month. Further, we estimate alternative models which use the number of Cooling Degree Days (CDDs) and Heating Degree Days (HDDs), showing that an increase in the number of HDDs is positively associated with the number and rate of disconnections, consistent with the findings in Table 2. Results appear in Supplementary Table S7.

The model estimates indicate several other sociodemographic factors that are associated with higher levels and rates of utility disconnections. Consistent with past research, the results suggest more disconnections among families with young children. A 10% increase in the share of a zip code that has children under the age of 5 years old is associated with an additional 15.05 monthly disconnections, equating to roughly 181 additional disconnections per year, and a 2.7% increase in disconnection risk for each additional 1% of the population with young children. Both the share of population over the age of 65 and a higher median income in a zip code correlate with a decrease in disconnections, consistent with past research.

With respect to housing characteristics, the total number of households per 1000 is positively associated with disconnections; there are more disconnections in more populous zip codes. Contrary to expectations, the coefficient on share of households who rent is negative, which suggests that an increase in the number of renters is associated with fewer disconnections. A potential explanation for this finding pertains to specific attributes of California's housing market, since California has the highest percentage of households who rent rather than own of any US state (45% of occupied housing units). This high rate includes Los Angeles, where households are served by LADWP, the utility service with the lowest disconnection rate in our sample, where 62% of all occupied units are occupied by renters[14].

Higher energy costs are also associated with both the level and rate of disconnections in California zip codes. Consistent with expectations, areas with higher energy prices also experience a higher number and rate of disconnections. The utility fixed effects estimate the number of additional disconnections of each IOU compared to LADWP (the excluded category); PG&E, SoCal Edison, and SDG&E disconnected on average an additional 34, 66, and 26 households per month, respectively.

Finally, we further examine housing conditions, which past empirical work has shown to be a contributing factor to higher rates of energy insecurity, including disconnections (see, e.g., Graff et al.[8]). Although we do not have a direct measure of deficient housing conditions, we include a set of variables that serve as reasonable proxies;

Table 3 | Determinants of the total number of utility disconnections, by individual utility

	PG&E total disconnections	SoCal Edison total disconnections	SDG&E total disconnections	LADWP total disconnections
Black population percent	1.884***	0.572***	1.740***	0.144***
	(0.064)	(0.066)	(0.129)	(0.007)
Hispanic population percent	0.285***	0.586***	0.349***	0.014**
	(0.019)	(0.038)	(0.031)	(0.006)
Percent of children under 5	0.524***	2.177***	−0.461*	0.949***
	(0.141)	(0.353)	(0.275)	(0.068)
Over 65%	0.022	0.202*	−0.065	−0.056**
	(0.049)	(0.110)	(0.090)	(0.028)
Median income per $1000	−0.129***	−0.001	−0.101***	−0.085***
	(0.014)	(0.043)	(0.034)	(0.006)
Renter percent	0.029	−0.519***	0.063	−0.012**
	(0.039)	(0.092)	(0.068)	(0.005)
Total households per 1000	3.781***	6.746***	2.649***	1.077***
	(0.058)	(0.099)	(0.068)	(0.017)
Energy costs per $1000	7.765***	2.280*	12.404***	4.515***
	(0.665)	(1.199)	(1.249)	(0.242)
Monthly average temperature	−1.302***	0.956***	−0.156	0.255***
	(0.138)	(0.235)	(0.350)	(0.051)
Protected days	−1.036***	0.198	0.389*	0.266***
	(0.080)	(0.127)	(0.200)	(0.035)
Housing controls?	Yes	Yes	Yes	Yes
Month FE?	Yes	Yes	Yes	Yes
Year FE?	Yes	Yes	Yes	Yes
Observations	12,487	9118	1683	28,422
R^2	0.486	0.564	0.753	0.333

Cells contain OLS coefficients, with robust standard errors in parentheses. Two-sided tests were used for all analyses.
Levels of statistical significance are denoted by p values as follows: $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

the type of home, the age of homes and the number of rooms in the home. All variables are measured as percentage of each zip code (e.g., 5% of homes were built between 1960 and 1979 in a given zip code). Somewhat surprisingly, there is not an indication that older homes experience more disconnections. There does appear, however, to be a positive relationship between the size of the home and the likelihood of disconnection.

Next, we re-estimate our models separately for each of the four utilities in the dataset to evaluate the degree to which the patterns of disconnections observed when pooling the data also emerge for each of the utilities independently. Results, displayed in Table 3, show racial and ethnic disparities in disconnections for each utility, but also suggest some differences in magnitudes across the utilities. Specifically, the three IOUs in the sample have substantially higher levels of disconnections in zip codes with a higher number of Black and Hispanic households compared to LADWP. The model estimates suggest that a 10% increase in share of Black households in a zip code corresponds to an additional 226, 68, and 208 yearly disconnections for PG&E, SoCal Edison, and SDG&E, respectively. The corresponding number for LADWP is an additional 17 disconnections. A 10% increase in the share of Hispanic households is associated with 34, 70, 42, and 2 additional yearly disconnections for PG&E, SoCal Edison, SDG&E, and LADWP, respectively.

While our analysis does not allow for a causal explanation as to why significant racial disparities in disconnections persist, this finding does provide suggestive evidence that utility practices may be a substantial contributor. Not only are racial disparities notably larger for those households served by IOUs, California IOUs have a less racially diverse customer base than does LADWP. The mean Black percentage of a zip code served by an IOU in our dataset is less than half that of LADWP (4.4% compared to 9.4%), and the mean Hispanic percentage of a zip code served by LADWP is 8% greater (41% compared to 33%). If disparities were driven by other factors (e.g., behavioral or housing differences) we would expect LADWP to have the largest disparities because they have a considerably larger share of Black and Hispanic households.

While our primary model shows a negative association between temperature and utility disconnections, suggesting that lower temperatures increase shutoffs, Table 3 reveals that this effect is driven by PG&E. For SoCal Edison and LADWP, the coefficients are positive and statistically significant. Geographically, households served by PG&E are concentrated in Northern and Central California, where temperatures are on average cooler than those in Southern California's hotter climate, according to the California Heat Assessment Tool[15]. Supplementary Fig. S1 shows the distribution of disconnections by average monthly temperature at the utility level. These findings suggest that more extreme weather drives disconnections, but the directionality of the effect depends on geography and may further be influenced by utility decision-making.

The results highlight other inter-utility disparities as well. Energy costs are a large and significant contributor to disconnections across all utilities, but the effect for PG&E and SDG&E is substantially greater than for residents serviced by LADWP. Moreover, disconnection protections were strongly and statistically associated with a decrease in disconnections for households served by PG&E, but not for those serviced by SoCal Edison or SDG&E.

It is important to note that estimates of disparities at the utility level are likely less precise than the full sample models for two primary reasons. First, the sample sizes for the individual utility regression models are notably smaller. Additionally, there may be unobservable factors such as discretionary behavior by utilities or differential behavior of households that are not captured in this analysis.

Discussion

This article analyzes the correlates of disconnections among four large electric utilities in the state of California. We study disconnections disclosed by utilities, which provides a different approach than most of the extant literature on energy insecurity that instead relies on self-reported customer data from surveys. To summarize the key results, we find that the level and rates of electric utility disconnections in a zip code are positively associated with its sociodemographic characteristics. Of particular note, we find large racial and ethnic disparities. An increase in the Black and Hispanic share of a zip code is associated with an increase in both overall disconnections and utility disconnection rates. These disparities exist even after controlling for other factors that are typically thought to explain patterns of disconnections, such as income, energy costs, and housing conditions. Among other key findings related to sociodemographic indicators, areas with more families with young children also experience higher rates of disconnections. These findings are consistent with those made by Cicala[10] in the context of Illinois utilities, now extended to California, and also accounts for findings about the correlates of energy insecurity from the US survey-based literature[6,8,9].

The finding of racial and ethnic disparities in disconnections, even while controlling for income, energy costs, and housing conditions, demonstrates that there is a distinct racial and ethnic element to disconnections that requires further investigation (see, e.g., Graff et al.[8] for a discussion). While this analysis uses utility-provided data to rule out some of the common suggestions in the literature that might explain why disparities persist, there are still a number of potential factors for which we cannot empirically account. One such factor is behavioral differences between households that may contribute to higher energy usage. However, we think this is an unlikely explanation considering the work of Cong et al.[16] suggesting that Black households are more likely to limit their energy consumption, resulting in a later "inflection point" at which they turn on air conditioning as temperatures increase. There is also evidence that Black and Hispanic households are less likely to receive energy assistance (see e.g., ref. 17), which may contribute to a higher likelihood of an utility disconnection. Additional factors may also exacerbate racial disparities, such as historical redlining and its role in lowering rates of home ownership and the quality of housing stock in communities with a higher share of Black population[18]. We encourage future scholarship to evaluate rigorously such empirical explanations.

Investigation of internal utility decision-making criteria and processes on which households are shut off from service may help further explain racial disparities. Because utility companies rarely make their disconnection procedures public, it is difficult to ascertain if there is a bias in decision-making that leads to more Black and Hispanic households being disconnected as compared to white households. Future research should examine utility decision-making and how it contributes to observed disparities in disconnection outcomes. Further, when designing policies and practices to limit utility disconnections, public utility commissions and other government agencies should consider not just overall rates of utility disconnections, but also implementation practices aimed at reducing racial and ethnic disparities.

Our analysis is further suggestive of differences in disconnections across the four utilities. In particular, we observe evidence that there is a greater incidence of disconnections and larger racial and ethnic disparities in disconnections among IOUs compared to LADWP, the one municipal utility in the study. Some past work has demonstrated differences in private and public utility performance in areas such as environmental compliance[19] and decarbonization[20], but this analysis suggests that these differences also pertain to levels and rates of utility disconnections. We do, however, interpret these results cautiously given the small number of utilities in this study. Further, California may present a unique case. From a public policy standpoint, California's regulations only limit utility disconnections in the event of extreme temperature as opposed to a more general, seasonal moratorium, while LADWP may be less inclined compared to other municipal utilities to disconnect households with bills past due. Suggestive of the latter is that LADWP self-imposed a moratorium on disconnecting households during the COVID-19 pandemic[21], and then followed that decision with an indefinite disconnection moratorium. Thus, it may be the case that LADWP is not representative of the behavior of most municipal providers, and the differences we find here are larger than might exist between IOUs and municipal utilities elsewhere in the country. In fact, evidence shows that municipal providers have some of the highest disconnection rates among all utilities in the United States for which data are available[22]. Future research should further examine patterns of disparities in disconnections across utility companies and types.

Finally, our analysis reveals a relationship between temperature and disconnections. While the weather coefficient in the full model is negative, our utility-level analysis reveals that this relationship is flipped for SoCal Edison, SDG&E, and LADWP, which tend to serve households in areas experiencing a higher prevalence of extreme heat. These results indicate that more extreme weather contributes to utility disconnections, but the effects are heterogeneous by region. This finding highlights the important role for public utility commissions and legislators in designing policies that account for increased incidence of extreme weather and the distribution of its impacts. These government officials can make policy adjustments that include the expansion of weather-based and seasonal disconnection moratoria, increased funding for energy assistance programs like LIHEAP, and investment in preventative solutions like weatherization and solar subsidies.

In the present analysis, we found that disadvantaged household characteristics such as race, ethnicity, and household composition are important predictors of disconnections, even after accounting for income, how much one pays for energy, and the condition of their home. An important next step is to address the question of why these disparities exist, including investigation into utility decision-making practices, expanding these analyses to other states and contexts, and further investigating the role of climate change in exacerbating overall disconnections and racial disparities.

Methods

To examine disparities in the likelihood of disconnection, we collected zip code level data from three of California's largest IOUs—SoCal Edison, PG&E, and SDG&E—as well as from LADWP. Data from IOUs came via public reporting mandated by California Public Utility Commission (CPUC) requirements in the 2010 Docket R.10-02-005 (stipulating regulated utilities must report disconnections, reconnections, and number of customer accounts) and the 2018 Docket R. 18-07-005 (stipulating that disconnections must be reported at the zip code level). Our analysis includes the number of utility disconnections due to nonpayment—note that this does not include disconnections due to outages—in each zip code from January 2018 through March 2020, when disconnections were suspended in response to the COVID-19 pandemic. Data from LADWP came from an open records request by the Indiana University Energy Justice Lab and includes zip code level disconnection in each year since 2013[22]. We restrict data to 2018–2020 to make comparisons between IOUs and LADWP, and use all available collected data within this time frame. The outcome measure, disconnections, includes two variations. The first is the total number of disconnections in each month, and the second is the disconnection rate in each month. For ease of interpretation, we measure the disconnection rate on a per 1000 customer basis.

Table 4 | Summary statistics for variables in study

	Overall	IOU	LADWP	Min	Max	SD
Disconnections	30.2	45.9	16.2	0	716	46.0
Disconnection rate (per 1000 households)	3.35	5.63	1.44	0	153.9	4.56
Percent of children under 5	5.9	5.8	5.9	0	24.3	2.2
Over 65%	14.6	17.0	12.9	0	100	73.4
Black population percent	7.2	4.4	9.4	0	81.1	11.1
Hispanic population percent	37.7	33.0	41.2	0	100	25.8
Median income (thousands $)	$69.1	$78.7	$61.3	$10.9	$247.6	$33.2
Renter percent	55.6	60.4	51.8	0	100	20.8
Total households (thousands)	11.4	8.9	13.5	5	33.5	6.9
Energy costs per 1000 (thousands $)	2.0	2.3	1.8	0.29	5.7	0.7
Monthly average temperature	16.9	16.0	17.7	−4.32	35.7	4.9
Protected days	1.20	1.9	0.64	0	31	3.2
Observations	52,286	22,447	28,422			

We merge the zip code level utility disconnection data with three other data sources. First, we merge them with the US Census Bureau's ACS zip-code level data on California households. The ACS provides 5-year estimates in every year between the census (e.g., 2018 data comprises 2013–2018). As the best approximation of the demographics of the zip codes in the sample, we use the 5-year estimate for each year of data: 2018, 2019, and 2020. ACS demographic data includes the percentage of those under 5 and over 65 years old in each zip code, percentage of each racial group, median income, total number of households, and what percentage of the district are renters.

Next, we merge data from the Department of Energy's LEAD Tool, which provides both energy burden and energy cost estimates at the census tract level. LEAD estimates the tract-level average energy costs and average energy burden using the ACS 2016 Microdata Sample, which it then calibrates to the U.S. EIA electric utility data. To match LEAD data, we used GIS to generate an area weight to estimate tract overlaps and generated a weighted value for each of the zip codes in our dataset.

Finally, we merge zip code level weather data from the PRISM dataset provided by Oregon State University. This provides us with a daily mean temperature for each zip code in California, which we then average for each month in our dataset from January 2018 through March 2020 to control for weather variation that may affect the likelihood that a household will be shut off from their utility service. Further, we use these data to construct the number of days in each month that IOUs had a disconnection protection in place by state law, i.e., when the temperature is above 100° on the 3-day look ahead. All summary statistics of the variables in our models are included in Table 4.

In addition, we include a series of fixed effects—utility, month, and year—to control for within utility and time variation. Utility fixed effects capture unobservable time-invariant utility-specific factors that may affect rates of disconnection, such as regulatory compliance (e.g., a household claiming exemption) or utility-specific assistance programs such as bill assistance, payment plans, or arrearage management programs. Month and year fixed effects capture unobserved factors that vary over time, such as economic and policy variation in the state of California. All data are analyzed using STATA.

There are a couple of important limitations to our analysis. While we include an expansive list of variables and fixed effects that we would expect to explain variation in disconnections, remaining sociodemographic disparities may be explained by unobserved factors. There are likely social, political, and economic considerations that go into disconnection decisions that we cannot directly measure. We also do not observe arrears among utility customers in our dataset. This uncertainty limits our ability to make inferences about the level of discretion that utility companies use when disconnecting households. Finally, we employ an ecological regression model, which may not be a fully accurate representation of disconnection disparities at the household level. However, the sociodemographic disparities we observe in our analysis are consistent with the survey-based literature which measures disconnections among households.

Reporting summary
Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability
The data generated in this study have been deposited in the Harvard Dataverse database. https://doi.org/10.7910/DVN/Y0OIRY.

Code availability
The code generated in this study has been deposited in the Harvard Dataverse database. https://doi.org/10.7910/DVN/Y0OIRY.

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Acknowledgements
This research was supported through funding by the Alfred P. Sloan Foundation. G-2022-19358, D.M.K. and S.C.

Author contributions
T.M., D.M.K., and S.C. all contributed equally to the conceptualization, research design, analysis, and writing of this article.

Competing interests
The authors declare no competing interests.

Additional information
Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41467-024-53913-y.

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Peer review information *Nature Communications* thanks the anonymous reviewers for their contribution to the peer review of this work. A peer review file is available.