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ORIGINAL ARTICLE

Differentiated disadvantage: class, race, gender, and residential energy efficiency inequality in the United States

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Abstract This study focuses on energy efficiency inequality in the United States. It examines the extent to which class, race, and gender, which have been shown to be key determinants of inequality in other areas, are related to energy efficiency inequality, measured by energy use intensity (EUI). Regression-based analysis of longitudinal data assembled from three waves of the Residential Energy Consumption Survey (2005, 2009, 2015), indeed, shows significant relationships between these variables and EUI in the residential sector. The results show that disadvantage in terms of EUI disparities in the African American community is differentiated by gender and class. Specifically, they show that while female-headed African American households fare worse than White households in terms of electricity EUI, male-headed African American households actually fare better. The relationship between being an African American household and residential EUI is conditioned by income: as incomes rise, EUI for housing units occupied by African American households decreases. This study underscores the importance of considering the joint influence of class, race, and gender when analyzing residential energy inequality, burdens, or insecurity.

Keywords Energy efficiency · Energy use intensity · Class · Race · Gender · Inequality · Intersectionality

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Introduction

This study examines energy efficiency inequality in the United States (U.S.). Analysts have suggested that improving efficiency in energy conversion and consumption is a relatively cheap way to meet the substantial energy needs of the country with some inherent measure of sustainability (IEA, 2014; Relf et al., 2017). As explained below, energy access (which can be improved through investments in energy efficiency), has significant implications for the well-being of individuals and families across the country.

The U.S. has, over the past few decades, experienced substantial improvements in energy use efficiency (Relf et al., 2017).[1] The question is whether

[1] Information retrieved 12/12/19 from: https://www.eia.gov/todayinenergy/detail.php?id=9951

there has been an equitable distribution of this generally desirable situation across the social spectrum. There is extensive research showing that certain social groups in the U.S.—people of color, women, and the poor or low income—are significantly more likely to experience energy poverty and insecurity (Bednar & Reames, 2020; Bohr & McCreery, 2019; Brown et al., 2020; Hernández & Bird, 2010; Kontokosta et al., 2019; Sovacool, 2012; Wang et al., 2021). We take this important line of work further by examining the relationships between class status, race, and gender, on the one hand, and energy efficiency inequality on the other. An important component of our study is examining whether and how energy efficiency inequality is related to the pairwise intersections of these variables (class status, race, and gender). Although not directly considered in this study, energy efficiency inequality is likely one of the factors contributing to the energy poverty and insecurity documented in the U.S. among the groups identified above.

Examining this subject is extremely important, given the energy access implications of efficiency improvement (Brown et al., 2020; Drehobl & Ross, 2016). There is evidence that energy-burdened or insecure households/families are more likely to experience poverty and food insecurity (Bohr & McCreery, 2019). This is likely because such households tend to spend larger proportions of their resources/income on energy, which is generally a nondiscretionary area of spending (especially during months requiring home heating). Energy poverty and insecurity have also been found to undermine physical and/or mental health (Ballesteros-Arjona et al, 2022; Child Health Impact Working Group, 2007; Frank et al., 2006; Liddell and Guiney, 2015; Sovacool, 2012). For example, Ballesteros-Arjona et al. (2022) found that perceived stress associated with difficulties in paying energy bills, using secondary heating equipment, and badly insulated homes decreased mental health. Studies also show that children in energy-burdened or insecure households are more likely to be identified by caregivers as being in poor health or experience hospitalization (Child Health Impact Working Group, 2007; Frank et al., 2006). This is partly because households experiencing energy burdens or insecurity tend to respond by cutting back on energy consumption, which can directly undermine residents' health and well-being, or by curtailing the consumption of other essential services, such as health care and education (Child Health Impact Working Group, 2007; Dillman et al., 1983; Sovacool, 2012). In contrast, high-income households often respond by investing in efficiency improvement (see Dillman et al., 1983). Thus, energy efficiency improvement provides an opportunity to mitigate the economic pain that often accompanies significant increases in energy prices, especially among the economically disadvantaged. It is also an effective way to limit the proportion of household income expended on energy without undermining well-being or elevating energy-related carbon intensity.

Results from the study show that class, race, and gender as well as their empirical intersections are associated with energy efficiency inequality in the U.S. Disadvantage in terms of energy efficiency in the African American community is differentiated by gender and class.

Conceptualizing energy efficiency

Improving energy efficiency is one of the longstanding approaches many American households have relied on to manage energy consumption and/or limit their impacts on the environment. Efficiency, in general, entails performing a given function with the least amount of resource input as possible. Energy efficiency therefore entails performing functions requiring energy, such as space heating and cooling, lighting, and powering of equipment and appliances, with less energy inputs. Efficiency is generally a function of technologies that minimize the energy needed, such as advanced home insulation materials and energy-efficient light bulbs and appliances (see Adua et al., 2019; Wiel et al., 1998). This contrasts with conservation, which entails reliance on behavioral changes to limit energy consumption.[2]

We draw on the notion of energy use intensity (EUI) to operationalize residential energy efficiency. In relation to housing units (or buildings, more generally), EUI is a ratio of the amount of energy used in a structure in relation to its size. It essentially entails energy consumption per square foot of a housing unit. Housing units (or homes) associated with higher EUI are considered less energy-efficient than those with

[2] https:/www.eia.gov/energyexplained/use-of-energy/efficiency-and-conservation.php

lower EUI, all else being the same. EUI has been used previously as a measure of energy efficiency in buildings (Zhao et al., 2016). Several cities in the U.S. use EUI as a measure of efficiency in their benchmarking and disclosure programs.[3] Our goal is to examine how class status, race, and gender are independently and jointly related to EUI in the residential sector, while controlling for the impacts of several measures of energy conservation behavior and other statistical control variables.

As mentioned earlier in this section, a housing unit's energy efficiency is largely a function of technology. While homes in the U.S. have grown in size quite substantially, technological innovations have helped limit the associated growth in EUI. U.S. homes built in 2000 and later are 30% bigger than those built prior to this period, but they consume only 2% more energy, which is attributed to improvements in equipment and building shell efficiency.[4] Empirical studies have reported negative relationships between a number of energy efficiency technologies and residential energy consumption (Adua, 2020; Adua et al., 2019; Vandenbergh and Gilligan, 2017). Energy efficiency inequality among social groups in the U.S. is therefore likely a function of disparities in access to these technologies, all else being the same.

Residential energy efficiency and inequality

Housing units in the U.S. have become more energy-efficient over the past several decades. This improvement, however, has not been uniform across all units. Newer homes tend to be more energy-efficient than older ones (Nadel et al., 2015; U.S. Department of Energy, 2008). Buildings with energy-efficient technologies or constructed in accordance with stricter state-sanctioned energy efficiency codes are associated with lower energy consumption (Adua et al., 2019; Jacobsen & Kotchen, 2013). Using residential energy billing data, Jacobsen and Kotchen (2013) found that Florida homes built in accordance with the state's stringent 2002 energy code consumed 4% and 6% less electricity and natural gas respectively. Adua et al. (2019) also find that households reporting that their homes are well or adequately insulated consumed considerably less energy (combined electricity and natural gas) than those reporting their homes as poorly or not insulated at all.

In relation to energy efficiency, some homes are better than others, which is an underlying source of energy efficiency inequality. This conclusion implies that some Americans live in or own homes that are more energy-efficient than others, essentially indicating the existence of energy efficiency inequality. These efficiency disparities result not only from differences in building shell efficiency, but also differences in the efficiency of appliances installed within homes. The question is, who gets to reside in these more efficient homes?

Given that inequality in all aspects of life in the U.S. does often fall along the social cleavages of class, race, and gender (Browne & Misra, 2003; Desilva & Elmelech, 2012; Morris & Western, 1999; Neckerman & Torche, 2007), we expect disparities in ownership or residence in energy-efficient housing units to be influenced in part by these variables. Indeed, there is some evidence that access to energy efficiency technologies, which are primary drivers of energy efficiency in residential buildings, varies by race/ethnicity (Lewis et al., 2019; Reames, 2016). As would be expected, they also vary by income gradient (Reames, 2016; Reames et al., 2018) . In fact, Reames et al. (2018) report that energy-efficient bulbs, quite paradoxically, are more expensive in poorer neighborhoods than wealthier ones. While it is hard to find empirical studies that have focused on the connections between gender and energy efficiency disparities, it is a reasonable hypothesis that female-headed families/households may not fare as well in residential energy efficiency as male-headed families/households, given the generally disadvantaged position of women in the U.S. (see Rothman, 2004). This study contributes to the energy poverty and insecurity literature, focusing on relationships between class (income), race, and gender and energy efficiency inequality. The unique contribution of this study is that it examines how these variables are independently and jointly related to energy efficiency (as measured by EUI).

Data and methods

To address the research questions posed in this study, we use three waves of the Residential Energy

[3] https://www.imt.org/resources/map-u-s-building-benchmarking-policies/

[4] Information retrieved 12/12/19 from: https://www.eia.gov/todayinenergy/detail.php?id=9951

Consumption Survey (RECS)—that is, the 2005 ($N = 4382$), 2009 ($N = 12{,}083$), and 2015 ($N = 5686$) waves. These are the three most recent versions of the survey with measures relevant to our research question. Each wave of the RECS is based on an area-probability sample of occupied housing units in the country; area-probability sampling is a complex multistage sampling procedure. The RECS is statutorily authorized by the U.S. Congress. The RECS, which collects data on energy consumption and other related variables, is an ongoing periodic cross-sectional survey conducted by the Energy Information Administration (EIA), U.S. Department of Energy. The first iteration of the survey was conducted in 1978.

For each of the RECS waves, data collection entailed interviewer administration of standardized questionnaires to households occupying housing units selected into the sample. Interviewers identified and interviewed household members within each housing unit/home knowledgeable about energy issues. For housing units where part or all of the associated energy costs are included in the rent, questionnaires were also administered to the appropriate rental agents. The EIA also surveyed responding households' energy utilities for several months of monthly energy consumption and expenditure figures, which were later annualized to create annual estimates.

Overall, the data collected in each wave of the survey are representative of all U.S. households. The data are publicly available online at a website maintained by the EIA. Detailed information about the survey, including sampling procedures, data preparation, and characteristics of the respondents, are available at the same website.[5] In this study, we use only variables (related to our research questions) that have been measured the same way across the three waves of the survey. Although described quite adequately below, Tables 1 and 2 provide additional information on each variable.

Dependent variable

The main dependent variable in this study is residential *energy efficiency*. We measure residential energy efficiency as energy consumption per square foot of home space, that is, EUI (energy use intensity). As noted earlier, the EIA obtained monthly energy consumption figures for several months from respondents' energy utility firms, which it later annualized to provide annual estimates. All else being the same, more energy-efficient homes would be associated with lower consumption per square foot, a desirable situation in respect of energy use and management. While conservation behavior may influence EUI, efficiency improvement is one of the primary driving forces (Zhao et al., 2016) .[6] The analysis we conduct controls for the potential confounding influence of conservation behavior. For the analysis conducted in this study, we consider energy efficiency related to electricity, natural gas, and a composite measure combining electricity and natural gas. Electricity and natural gas are the most widely used fuels in American homes. Summary statistics for these measures are reported in Table 1.

Independent variables

Three sets of independent variables are analyzed in this study: the *key independent* variables (class, race, and gender), *conservation behavior* (energy consumption-related behavioral actions), and *other statistical control variables*. *Class* is measured by annual composite household income from all sources. Response options for this measure were originally provided as income categories, but we recoded each option to its category midpoint. To ensure parity in income earned across the three survey waves used (2005, 2009, & 2015), we converted the 2005 and 2009 figures to 2015 real dollars. *Race* is measured by whether the responding householder identifies as White, African American/Black, or other race (American Indian or Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, and some other race). For simplicity and ease of describing our results, we will identify households by the race of the responding householder. The final key independent variable, *gender*, is measured by whether or not the responding householder identifies as female or male. While there may be other adults in a household, this item focuses specifically on the person who responded to the survey. Descriptive statistics for these variables are also reported in Table 1.

To assess the potential joint impacts of the key independent variables described above, which is an important component of the study, we create and use measures of pairwise intersections between indicators

5 https://www.eia.gov/consumption/residential/

6 https://www.eia.gov/todayinenergy/detail.php?id=38332

Table 1 Summary statistics

	2005		2009		2015		Combined 2005–2015	
	Mean/proportion	Std. error	Mean/proportion	Std. error	Mean/proportion	Std. error	Mean/proportion	Std. error
Dependent variable: resid. energy eff								
Resid. EUI, electricity, BTU	23,024.77	322.06	23,392.51	222.06	22,396.51	240.53	23,064.11	150.31
Resid. EUI, natural gas, BTU	25,612.94	695.29	24,128.96	519.21	18,097.10	342.74	22,874.09	327.80
Resid. EUI, combined, BTU	48,637.71	770.46	47,521.46	607.63	40,493.61	374.44	45,938.20	378.50
Key independent variables								
Real household income, 2015[a]	60,358.86	717.41	59,347.85	434.53	60,751.01	649.79	59,938.21	322.96
Race: White	0.72	0 .01	0.79	0.00	0.81	0.01	0.78	0.00
Race: African American	0.12	0.01	0.14	0.00	0.12	0.00	0.13	0.00
Race: Other	0.16	0.01	0.08	0.00	0.08	0.00	0.09	0.00
Gender: Female	0.56	0.01	0.53	0.01	0.56	0.01	0.54	0.00
Other independent variables: behavior								
Home heating temp., member at home	68.95	0.20	69.72	0.05	70.01	0.06	69.65	0.05
Home cooling temp., member at home:[b]								
40–64°F (i.e., 4.44–17.78 °C)	0.00	0.00	0.01	0.00	0.04	0.00	0 .01	0.00
65–75°F (i.e., 18.33–23.89 °C)	0.30	0.01	0.31	0.00	0.62	0.01	0 .39	0.00
76–96°F (i.e., 24.44–35.56 °C)	0.16	0.01	0.12	0.00	0.21	0.01	0.15	0.00
Freq. of dishwasher use:[c]								
Less than once per week	0.10	0.00	0.11	0.00	0.14	0.00	0.11	0.00
Once per week	0.08	0.00	0.09	0.00	0.11	0.00	0.09	0.00
2–3 times per week	0.20	0.01	0.19	0.00	0.22	0.01	0.20	0.00
4–6 times per week	0.11	0.00	0.10	0.00	0.13	0.00	0.11	0.00
At least once per day	0.10	0.00	0.11	0.00	0.08	0.00	0.10	0.00
Laundry, no. of wash loads:[c]								
1 load or less per week	0.07	0.00	0.07	0.00	0.10	0.00	0.08	0.00
2–4 loads per week	0.35	0.01	0.36	0.00	0.41	0.01	0.37	0.00
5–9 loads per week	0.30	0.01	0.29	0.00	0.23	0.01	0.28	0.00
10 or more loads per week	0.11	0.00	0.10	0.00	0.08	0.11	0.09	0.00
Laundry, wash temp.:[c]								
Hot	0.06	0.00	0.05	0.00	0.06	0.00	0.05	0.00
Warm	0.45	0.01	0.39	0.01	0.40	0.01	0.41	0.00

Table 1 (continued)

	2005		2009		2015		Combined 2005–2015	
	Mean/proportion	Std. error	Mean/proportion	Std. error	Mean/proportion	Std. error	Mean/proportion	Std. error
Cold	0.31	0.01	0.37	0.01	0.36	0.01	0.36	0.00
Other independent variables: statistical controls								
Energy expend., real 2015 $	1934.86	17.06	2020.68	11.52	1723.34	13.02	1927.38	7.94
No. of household members	2.57	0.02	2.57	0.02	2.55	0.02	2.56	0.01
Household member at home on typical weekday (yes = 1)	0.51	0.01	0.57	0.01	0.84	0.01	0.63	0.00
Region								
Region: Northeast	0.18	0.01	0.18	0.00	0.18	0.01	0.18	0.00
Region: Midwest	0.23	0.01	0.23	0.00	0.22	0.01	0.23	0.00
Region: South	0.37	0.01	0.37	0.01	0.38	0.01	0.37	0.00
Region: West	0.22	0.01	0.22	0.00	0.22	0.01	0.22	0.00
Heating degree days, 65°F (i.e., 18.33 °C)	4076.71	35.24	4196.77	21.01	3762.83	31.01	3929.96	19.42
Cooling degree days, 65°F (i.e., 18.33 °C)	1585.34	16.70	1383.46	10.38	1732.62	17.31	1618.72	10.62

[a] Response options for income were recorded as income categories. For the analysis, these were recoded to category midpoints. These descriptive statistics are based on the recoded versions of income and are in 2015 real dollars

[b] Proportion may not sum to 1 because of rounding

[c] For these items, proportion for legitimate skips/not applicable were computed, but not reported here. They were retained as categories in the regression analysis conducted in this study so as to not lose cases. Their coefficient are not reported, however

Table 2 Variables, measurement, and response values

Variable	Description/measurement	Response values
Residential EUI, electricity, BTU	Electricity consumption in British Thermal Units (BTU) divided by total home size (square feet)	5.156472–481,517.8 BTU/sqft
Residential EUI, natural gas, BTU	Natural gas consumption in British Thermal Units (BTU) divided by total size (square feet)	143.3134–1,143,220 BTU/sqft
Residential EUI, combined, BTU	Combined electricity and natural gas consumption in British Thermal Units (BTU) divided by total home size (square feet)	5.156472–1,270,370 BTU/sqft
Household income	Please tell me which category best describes the total combined income in the past 12 months of all members of your household living here from all sources	Response originally provided in 24 income categories for 2005 and 2009 and 8 categories for 2015 with slightly uneven intervals. These were recoded to category midpoints and converted to 2015 real dollars
Race	Which describes your/the householder's race? (Respondents were shown a card with a listing of various race groups in the United States: American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, White, Other (if volunteered)	Original options regrouped to "White," "African American or Black," and "Other"
Gender	Are you/Is the householder a male or a female?	1 = female; 0 = male
Home heating temp., member at home	Temperature when someone is home during the day	40–90 Fahrenheit (i.e., 4.44–32.22 °C)
Home cooling temp., member at home	Cooling temperature setting when someone is at home during the day	40–96 Fahrenheit (i.e., 4.44–35.56 °C): recoded to categories due to skewness
Frequency of dishwasher use	Frequency of dish washer use per week	1 = Less than once per week; 2 = once per week; 3 = 2–3 times per week; 4 = 4–6 times per week; and 5 = at least once per day
Laundry, no. of wash loads	Frequency of clothes washer use (number of loads per week)	1 load or less per week; 2–4 loads per week; 5–9 loads per week; 10 or more loads per week
Laundry, wash temp	Water temperature used for wash cycle	Hot, warm, cold
Home ownership	Is housing unit owned, rented, or occupied without payment of rent?	1 = Owned by someone in the household; 2 = rented; 3 = occupied without paying rent
Age	How old are you/is the householder?	16–96 years
Number of household members	Including yourself, how many people normally live in this household? Do not include anyone who is just visiting, those away in the military, or children who are away at college	1–20 people
Household member at home on typical weekday	On a typical weekday, is there someone at home all day?	Responses ranged from 0 to 5 people, but this was recoded to a dummy variable: 0 = no member at home all day on typical weekday; 1 = at least one member at home all day on a typical weekday

Table 2 (continued)

Variable	Description/measurement	Response values
Home/housing type	Interviewer-recorded type of housing (single-family detached house; single-family attached house; apartment in a building with 2–4 units; apartment in a building with 5 or more units; mobile home)	Original response options recoded to: (1) single-family detached; (2) other
Region	Census region of housing unit	1 = Northeast; 2 = midwest; 3 = south; 4 = west
Heating degree days, 65°F (i.e., 18.33 °C)	Heating degree days in year, base temperature 65°F (i.e., 18.33 °C)	0–12,525
Cooling degree days, 65°F (i.e., 18.33 °C)	Cooling degree days in year, base temperature 65°F (i.e., 18.33 °C)	0–6607

associated with class, race, and gender through statistical interactions: class indicators by race indicators, class indicators by gender indicators, and race indicators by gender indicators. We consider only pairwise interactions because of the absence of consistent three-way interaction effects. While our approach has some limitations, it is consistent with the *intracategorical* methodological approach to intersectional analysis (McCall, 2005). The intracategorical approach is one of three methodological approaches to intersectional analysis.[7] It highlights how positions or statuses defined within a given category, such as being female in gender categorization, intersects with specific positions or statuses in other categories, such as being African American (for race/ethnicity) and middle-income status (for class). McCall illustrates this by observing that "…an Arab American, middle-class, heterosexual woman is placed at the intersection of multiple categories (race-ethnicity, class, gender, and sexual)…" (p. 1781).

The measures of *conservation behavior* included in the study are home heating temperature settings when there is at least one household member at home and home cooling temperature settings when there is at least one household member at home. For context, home heating and cooling account for the largest proportion of energy consumption in the residential sector. Other measures of conservation behavior operationalized in this study are frequency of dishwasher use, number of laundry wash loads per week, and temperature of water used for laundry. In including this set of variables in the models, our goal is to evaluate whether any observed disparities in EUI are related to conservation behavior. Summary statistics for this set of variables are available in Table 1.

[7] The other approaches are *anticategorical* and *intercategorical*. The *anticategorical approach* focuses on the deconstruction of categories. The approach considers social life as irreducibly complex, which makes "…fixed categories anything but simplifying social fictions that produce inequalities in the process of producing differences" (McCall, 2005:1173). According to McCall, the anticategorical approach renders the use of categories suspect. The *intercategorical approach* is also referred to as the categorical approach. The approach observes that "there are relationships of inequality among already constituted social groups, as imperfect and ever changing as they are, and takes those relationships as the center of analysis" (McCall, 2005:1785). From this approach, therefore, researchers' task is to explain those relationships, which entails starting with categories.

The *other statistical control variables* included in the study are age of householder (i.e., the responding household member), number of household members, presence of a household member at home on a typical weekday (0/1), home ownership (own, rent, occupy without paying rent), home type (single-family detached versus all others), region (northeast, midwest, south, and west), heating degree days (degrees per day that the average temperature of the area a home is located is lower than the reference temperature level of 65°F [i.e., 18.33 °C]), and cooling degree days (degrees per day that the average temperature of the area a home is located is higher than the reference temperature level of 65°F [i.e., 18.33 °C]). Heating and cooling degree days tap energy requirement for heating and cooling respectively. We include these control variables because prior studies suggest that they may be important drivers of residential energy consumption (Adua, 2020; Adua et al., 2019).

Model estimation

Stepwise regression models are estimated for energy efficiency inequality related to each of electricity, natural gas, and combined electricity-natural gas consumption. In the first iteration, we estimate models without considering pairwise interactions between income, race, and gender and excluding all the measures of conservation behavior. Several standard control variables are included in these models (model 1 of Tables 4, 5, 6). In the second iteration, we estimate models that consider pairwise interactions between income, race, and gender as well as the standard statistical control variables. Measures of conservation behavior still remain excluded from this set of models (model 2 of Tables 4, 5, 6). In the final step, we estimated models that include pairwise interactions between the key variables of interest (income, race, and gender), measures of conservation behavior, and statistical control variables (model 3 of Tables 4, 5, 6).

The data used in this study have a nesting structure (i.e., responding households nested within survey years), which suggests pooled ordinary least squares (OLS) regression analysis may not be appropriate. Finding, indeed, that OLS is inappropriate for modeling EUI disparities related to natural gas and combined electricity-natural gas consumption (Tables 5 and 6), we opted for the equivalent of fixed effects regression analysis for these models. In practical terms, we dummy-coded survey year and included two of the dummy variables (survey years 2009 and 2015) as predictors in these models. The diagnostics supporting use of fixed effects regression show that the joint effects of the survey year dummy variables included in each of these models are statistically significant. For EUI inequality related to electricity use (Table 4), the diagnostic tests suggest that the joint effect of the survey year dummies is not statistically significant. For these models, we estimated pooled OLS regression models. All the models are estimated with probability-weighted robust standard errors.

Prior to estimating our final models, we conducted several other diagnostics—checking for multicollinearity, heteroskedasticity, autocorrelation, and potential interactions between some of the other variables included in the model. We found multicollinearity to be an issue only when the control variables and interaction between heating degree days and home heating temperature are included in the model (see Table 3). However, this observed collinearity can be safely ignored, given that it arises only when the statistical controls are included in the models. Without including the statistical control variables and interaction between heating degree days and heating temperature settings, the mean variance inflation factors for the models range between 1.62 and 1.74, substantially lower than the recommended cut-off point of 10 (Kim, 2019). The diagnostics did not identify any issues of heteroskedasticity and autocorrelation in the model. We did identify interactions between some of the key independent variables and between heating degree days and home heating temperature settings.

Results

The first set of models (i.e., those without interaction terms and measures of conservation behavior) show that energy efficiency (as measured by energy use intensity, EUI) varies across U.S. households by income and race (Tables 4, 5, 6, model 1). Across all three measures of EUI (electricity, natural gas, and total), income is found to be negatively related to EUI (model 1 of Tables 4, 5, 6). Households of other racial groups (i.e., responding householder identifying as other race) are associated with lower electricity consumption EUI (Table 4, model 1). In terms of natural gas consumption, both African American

Table 3 Variance inflation factors (VIF) for independent variables

	Full model estimates for variables		
	Electricity model	Natural gas model	Total model
Income, real 2015 dollars	1.48	1.61	1.59
Female householder	1.18	1.05	1.04
Race: African American householder	2.28	2.68	2.64
Race: Other race householder	1.10	1.14	1.11
African American*Female	2.86	Not in model	Not in model
Income*African American	Not in model	2.51	2.49
Home heating temp., member home	1.06	3.04	2.49
Home heating temp*heating degree days, 65°F	Not in model	141.98	128.10
Home cooling temp., member home (ref. = 40–64°F [4.44–17.78 °C]):[b]			
65–75°F (18.33–23.89 °C)	16.85	16.91	16.91
76–96°F (24.44–35.56 °C)	9.84	9.40	9.90
Freq. of dishwasher use (ref. = less than once per week):[b]			
Once per week	1.70	1.74	1.70
2–3 times per week	2.38	2.46	2.39
4–6 times per week	1.94	2.02	1.94
At least once per day	1.92	1.97	1.93
Laundry wash loads per week (ref. = 1 load/less):[b]			
2–4 loads per week	3.91	3.86	3.91
5–9 loads per week	3.97	3.96	4.00
10 or more loads per week	2.52	2.53	2.53
Laundry, wash temp. (ref. = hot):[b]			
Warm	5.08	4.95	5.08
Cold	4.94	4.67	4.95
Age of householder	1.50	1.49	1.51
Number of household members	1.62	1.65	1.63
Member at home on typical weekday	1.16	1.23	1.22
Renting home (ref. = own)	1.91	2.00	1.92
Occupy home, paying no rent (ref. = own)	1.02	1.02	1.02
Home type (ref. = single-family detached)	1.73	1.86	1.73
Midwest (ref. = northeast)	1.84	1.95	1.86
South (ref. = northeast)	3.15	2.69	3.20
West (ref. = northeast)	2.35	2.52	2.35
Heating degree days, 65°F (18.33 °C)	4.83	141.36	130.13
Cooling degree days, 65°F (18.33 °C)	3.81	3.06	3.87
Mean VIF	7.02	14.33	13.84
	Statistical control variables exclude from models		
	Electricity model	Natural gas model	Total model
Income, real 2015 dollars	1.04	1.16	1.14
Female householder	1.16	1.02	1.02
Race: African American householder	2.67	2.52	2.49
Race: Other race householder	1.02	1.02	1.02
African American*Female	2.83	Not in model	Not in model
Income*African American	Not in model	2.46	2.45
Mean VIF	1.74	1.64	1.62

Table 4 Regression of electric energy use intensity (EUI) on class, race, gender, measures of conservation behavior and other covariates[a]

	Model 1	Model 2	Model 3
	b (Robust S.E.)	b (Robust S.E.)	b (Robust S.E.)
Key ind. variables			
Income, real 2015 dollars	−0.05 (0.00)***	−0.05 (0.00)***	−0.06 (0.00)***
Female householder	−414.75 (285.60)	−687.62 (305.35)*	−1178.62 (312.90)***
Race: African American householder	−773.66 (431.64)	−2174.97 (664.28)**	−1682.66 (680.78)*
Race: Other race householder	−2163.77 (463.52)***	−2167.54 (463.59)***	−1496.05 (453.84)***
Income*African American	-	NS (excluded)	NS (excluded)
Income*other race	-	NS (excluded)	NS (excluded)
Income*female	-	NS (excluded)	NS (excluded)
African American*female	-	2263.21 (836.83)**	2084.11 (844.50)*
Other race*female	-	NS (excluded)	NS (excluded)
Other ind. variables: conservation behavior			
Home heating temp., member home	-	-	58.33 (21.82)**
Home cooling temp., member home (ref. = 40–64°F [4.44–17.78 °C]):[b]			
65–75°F (18.33–23.89 °C)	-	-	1102.54 (1215.98)
76–96°F (24.44–35.56 °C)	-	-	−1392.59 (1226.81)
Freq. of dishwasher use (ref. = less than once per week):[b]			
Once per week	-	-	−153.19 (482.85)
2–3 times per week	-	-	678.93 (428.86)
4–6 times per week	-	-	1284.34 (567.85)*
At least once per day	-	-	2467.67 (824.14)**
Laundry wash loads per week (ref. = 1 load/less):[b]			
2–4 loads per week	-	-	3238.27 (451.21)***
5–9 loads per week	-	-	5692.75 (492.26)***
10 or more loads per week	-	-	7538.13 (735.54)***
Laundry, wash temp. (ref. = hot):[b]			
Warm	-	-	−612.49 (730.59)
Cold	-	-	192.54 (769.29)
Other ind. variables: stats. controls			
Age of householder	−76.42 (12.15)***	−75.96 (12.13)***	−62.80 (11.87)***
Number of household members	1412.87 (116.59)***	1411.34 (116.48)***	766.08 (132.44)***
Member at home on typical weekday	763.06 (317.83)*	759.13 (317.70)*	441.03 (305.34)
Renting home (ref. = own)	646.85 (521.96)	636.64 (522.24)	713.57 (515.64)
Occupy home, paying no rent (ref. = own)	3322.07 (1346.41)*	3357.10 (1343.13)*	3199.44 (1349.59)*
Home type (ref. = single-family detached)	−7874.27 (457.84)***	−7885.43 (458.06)***	−8422.12 (501.21)***
Midwest (ref. = northeast)	3550.62 (422.56)***	3551.18 (422.61)***	3137.86 (404.15)***
South (ref. = northeast)	13,305.76 (493.48)***	13,324.34 (493.51)***	12,470.09 (502.33)***
West (ref. = northeast)	5465.53 (482.58)***	5488.21 (482.78)***	5844.44 (479.10)***
Heating degree days, 65°F (18.33 °C)	0.83 (0.12)***	0.83 (0.12)***	0.59 (0.12)***
Cooling degree days, 65°F (18.33 °C)	2.73 (0.21)***	2.73 (0.21)***	2.50 (0.22)***
Model statistics			
Intercept	16,886.46	17,024.52	11,319.59
N	22,150	22,150	21,147
R-squared	0.21	0.21	0.24

NS: not significant

[a]Year effect not significant in this model

[b]Although not reported in this table, we included the *Not Applicable/legitimate skip* response categories of these variables in the regression analysis so as to not lose too cases

$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

Table 5 Regression of natural gas energy use intensity (EUI) on class, race, gender, measures of conservation behavior and other covariates

	Model 1	Model 2	Model 3
	b (Robust S.E.)	b (Robust S.E.)	b (Robust S.E.)
Key ind. variables			
Income, real 2015 dollars	− 0.09 (0.01)***	− 0.07 (0.01)***	− 0.05 (0.02)**
Female householder	− 1634.15 (1050.08)	− 1648.18 (1050.36)	− 1782.51 (1139.63)
Race: African American householder	12,601.22 (1920.54)***	18,527.38 (3889.66)***	15,527.71 (3907.49)***
Race: Other race householder	2602.65 (1309.29)*	2646.72 (1310.88)*	1618.12 (1304.06)
Income*African American	-	− 0.12 (0.05)**	− 0.11 (0.05)*
Income*other race	-	NS (excluded)	NS (excluded)
ncome*female	-	NS (excluded)	NS (excluded)
African American*female	-	NS (excluded)	NS (excluded)
Other race*female	-	NS (excluded)	NS (excluded)
Other ind. variables: conservation behavior			
Home heating temp., member home	-	-	− 54.61 (74.32)
Heating temp*HDD 65	-	-	0.14 (0.04)***
Home cooling temp., member home (ref. = 40–64°F [4.44–17.78 °C]):[a]			
65–75 (18.33–23.89 °C)	-	-	4206.01 (2344.48)
76–96 (24.44–35.56 °C)	-	-	2617.10 (2335.66)
Freq. of dishwasher use (ref. = less than once per week):[a]			
Once per week	-	-	955.35 (986.47)
2–3 times per week	-	-	1181.26 (864.91)
4–6 times per week	-	-	2316.32 (1644.53)
At least once per day	-	-	4555.59 (3490.81)
Laundry wash loads per week (ref. = 1 load/less):[a]			
2–4 loads per week	-	-	1641.99 (1278.81)
5–9 loads per week	-	-	1865.51 (1233.63)
10 or more loads per week	-	-	2570.88 (1595.77)
Laundry, wash temp. (ref. = hot):[a]			
Warm	-	-	− 166.90 (1147.41)
Cold	-	-	− 40.60 (1506.53)
Other ind. variables: stats. controls			
Age of householder	− 25.99 (49.55)	− 24.10 (49.68)	− 37.76 (50.84)
Number of household members	246.29 (402.44)	267.89 (401.75)	− 108.06 (516.46)
Member at home on typical weekday	2428.65 (1225.52)*	2364.64 (1220.37)	1959.53 (1191.03)
Renting home (ref. = own)	6505.79 (2115.31)**	6310.51 (2102.46)**	3661.72 (1952.81)
Occupy home, paying no rent (ref. = own)	2033.00 (3065.43)	1942.94 (3067.64)	− 286.94 (2978.08)
Home type (ref. = single-family detached)	− 9773.98 (1741.84)***	− 9841.77 (1743.00)***	− 9365.29 (1980.64)***
Midwest (ref. = northeast)	788.26 (1744.36)	655.75 (1729.47)	1394.00 (1661.13)
South (ref. = northeast)	− 7287.84 (1282.85)***	− 7222.28 (1284.37)***	− 5652.87 (1373.58)***
West (ref. = northeast)	− 5893.35 (1274.64)***	− 5876.99 (1276.14)***	− 4630.07 (1284.25)***
Heating degree days, 65°F (18.33 °C)	3.11 (0.31)***	3.13 (0.31)***	− 6.71 (2.67)*
Cooling degree days, 65°F (18.33 °C)	− 1.16 (0.43)**	− 1.17 (0.43)**	− 0.50 (0.51)
Survey year: 2009 (ref. = 2005)	− 2833.65 (1080.14)**	− 2764.87 (1082.82)*	− 2204.72 (1078.77)*
Survey year: 2015 (ref. = 2005)	− 9951.57 (982.30)***	− 9964.69 (983.15)***	− 6408.83 (1078.92)***
Model statistics			
Intercept	41,261.61***	40,419.00***	30,282.08**

Table 5 (continued)

	Model 1	Model 2	Model 3
N	13,487	13,487	12,960
R-squared	0.15	0.15	0.17

NS: not significant

[a]Although not reported in this table, we included the *Not Applicable/legitimate skip* response categories of these variables in the regression analysis so as to not lose too cases. $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

households (i.e., responding householder identifying as African American) and households of *other racial* groups are associated with higher EUIs than White households (Table 5, model 1). Finally, the results show that being an African American household is associated with higher combined electricity and natural gas EUI than being a White household (Table 6, model 1). These findings suggest the potential existence of race-based energy efficiency inequality. As explained earlier in this paper, lower EUI suggests greater energy efficiency, all things being equal. Is there more to these relationships? To what extent are these relationships conditioned by the pairwise interactions of the independent variables?

In the second models shown in Tables 4, 5 and 6, we introduce pairwise interactions of the key independent variables. There is evidence of interactions between race and the other variables (income and gender) conditioning the relationships. The relationship between being an African American household and electricity EUI varies by whether or not the responding householder is female (Table 4, model 2). The effect of race (being African American household) on electricity EUI is 88.24 BTU/sq. ft. higher than White households for respondents identifying as female householders (i.e., $-2174.97+2263.21*1$ [i.e., female holder]), but -2174.97 BTU/sq. ft. lower than White households for respondents identifying as male householders (i.e., $-2174.97+2263.21*0$ [i.e., male householder]. This pattern of conditional relationships between race and gender and electricity EUI remains, even after measures of conservation behavior are included in the model (Table 4, model 3). The key thing to note here is that in terms of electricity consumption, only the relationships between race and gender and EUI are conditioned by the pairwise interactions of these predictors (race*gender).

Being a household of other race remains negatively related to electricity EUI (Table 4, model 2), and the pattern remains unchanged even after conservation behavior measures are included in the model (Table 4, model 3). Income remains negatively related to electricity EUI (unconditioned by any of the other key independent variables): $b=-0.05$ (prob. <0.001).

In both the natural gas and combined electricity-natural gas consumption models, the data suggests income intersects with race to influence the associated EUI (Tables 5 and 6, models 2 and 3). For both models, income is related to EUI, but this relationship varies by race. This pattern of relationships remains unchanged even after the influence of measures of conservation behavior is statistically held constant. From the models that control for measures of conservation behavior (model 3 of Tables 5 and 6), the influence of income on EUI for African American households (African American household = 1) are -0.16 (i.e., $-0.05+[-0.11 \quad *1]$) and -0.13 (i.e., $-0.05+[-0.08 \quad *1]$) for the natural gas and combined electricity-natural gas models respectively, while for White households (White household = 0), the effects are -0.05 (i.e., $-0.05+[-0.11 \quad *0]$) and -0.05 (i.e., $-0.05+[-0.08 \quad *0]$) for the natural gas and combined electricity-natural gas models respectively. In terms of the logical flip side of these findings, we note that the relationships between being an African American household and natural gas and combined electricity-natural gas EUI are conditional on income. We provide one illustration here. For an African American household, combined electricity-natural gas EUI when controlling for measures of conservation behavior drops from 13,346.92 BTU/sq.ft. (i.e., 13,415.98 + [−0.05 *1381.119]) to 5528.145 BTU/sq.ft. (i.e., 13,415.98 + [−0.05 *157,756.7]) if its annual income shift from the minimum value in the data used (1381.119) to the maximum value (157,756.7). The findings here, in effect, show that higher-income African American households use less energy per square foot of home space

Table 6 Regression of total energy (electricity and natural gas) use intensity (EUI) on class, race, gender, measures of conservation behavior and other covariates

	Model 1	Model 2	Model 3
	b (Robust S.E.)	b (Robust S.E.)	b (Robust S.E.)
Key ind. variables			
Income, real 2015 dollars	−0.08 (0.01)***	−0.07 (0.01)***	−0.05 (0.01)***
Female householder	−527.07 (813.14)	−527.75 (812.82)	−832.00 (892.59)
Race: African American householder	11,214.73 (1425.02)***	15,344.59 (2787.80)***	13,415.98 (2806.35)***
Race: Other race householder	1923.29 (1135.23)	1958.74 (1136.35)	2007.94 (1149.20)
Income*African American	-	−0.09 (0.03)**	−0.08 (0.03)*
Income*other race	-	NS (excluded)	NS (excluded)
Income*female	-	NS (excluded)	NS (excluded)
African American*female	-	NS (excluded)	NS (excluded)
Other race*female	-	NS (excluded)	NS (excluded)
Other ind. variables: conservation behavior			
Home heating temp., member home	-	-	−104.94 (52.30)*
Heating temp*HDD 65	-	-	0.16 (0.03)***
Home cooling temp., member home (ref. = 40–64°F [4.44-–7.78 °C]):[a]			
65–75 (18.33–23.89 °C)	-	-	2628.59 (2175.32)
76–96 (24.44–35.56 °C)	-	-	−757.96 (2159.64)
Freq. of dishwasher use (ref. = less than once per week):[a]			
Once per week	-	-	830.43 (867.59)
2–3 times per week	-	-	1363.40 (767.29)
4–6 times per week	-	-	2864.57 (1419.72)*
At least once per day	-	-	4637.36 (2928.11)
Laundry wash loads per week (ref. = 1 load/less):[a]			
2–4 loads per week	-	-	2722.54 (1058.52)*
5–9 loads per week	-	-	4330.29 (1056.16)***
10 or more loads per week	-	-	6037.91 (1407.71)***
Laundry, wash temp. (ref. = hot):[a]			
Warm	-	-	−1640.96 (1113.86)
Cold	-	-	−1870.09 (1368.58)
Other ind. variables: stats. controls			
Age of householder	−69.73 (40.31)	−68.66 (40.41)	−80.34 (40.67)*
Number of household members	1717.66 (336.03)***	1734.32 (336.01)***	1008.39 (426.92)*
Member at home on typical weekday	2716.52 (978.87)**	2679.61 (976.91)**	1957.00 (940.83)*
Renting home (ref. = own)	5933.03 (1628.50)***	5804.25 (1619.31)***	3914.54 (1535.78)*
Occupy home, paying no rent (ref. = own)	4490.72 (2450.20)	4444.55 (2456.07)	3412.21 (2450.34)
Home type (ref. = single-family detached)	−11,525.58 (1262.53)***	−11,592.72 (1261.56)***	−11,602.45 (1424.05)***
Midwest (ref. = northeast)	8405.59 (1523.67)***	8328.36 (1517.82)***	8007.44 (1455.32)***
South (ref. = northeast)	−2674.21 (1111.68)*	−2606.31 (1111.22)*	−2810.62 (1245.23)*
West (ref. = northeast)	−1284.73 (1131.42)	−1248.62 (1132.34)	642.99 (1117.20)
Heating degree days, 65°F(18.33 °C)	1.29 (0.28)***	1.30 (0.28)***	−9.97 (1.97)***
Cooling degree days, 65°F (18.33 °C)	0.56 (0.39)	0.57 (0.39)	0.89 (0.43)*
Survey year: 2009 (ref. = 2005)	−1734.45 (870.06)*	−1683.31 (871.40)	−762.33 (872.89)
Survey year: 2015 (ref. = 2005)	−8895.34 (810.71)***	−8888.43 (810.45)***	−7225.96 (893.17)***
Model statistics			
Intercept	48,718.53	48,086.12	48,867.04

Table 6 (continued)

	Model 1	Model 2	Model 3
N	22,150	22,150	21,147
R-squared	0.10	0.10	0.12

NS: not significant

[a]Although not reported in this table, we included the *Not Applicable/legitimate skip* response categories of these variables in the regression analysis so as to not lose too cases. $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

than White households, which suggest that they may be living in homes that are more energy efficient, and/or as well use more energy-efficient appliances. The results show the negative relationship between being household of *other race* and natural gas EUI disappearing once we control for measures of conservation behavior (Table 5, model 3).

We now briefly comment on the relationships between some of the measures of conservation behavior and other statistical control variables and EUI, focusing on model 3 of Table 6 (combined electricity-natural gas EUI). The relationships between home heating temperature settings and combined electricity-natural gas EUI is conditional on heating degree days (−104.94 + [0.16*number of heating degree days]. Net of all the other variables included in the model, cooling temperature settings do not seem to be related to combined electricity and natural gas EUI. Number of laundry wash loads per week is positively related to combined electricity-natural gas consumption EUI, but laundry water temperature does not seem to be related to the outcome variable (Table 6, model 3). Several of the other statistical control variables are significantly related to combined electricity-natural gas EUI. While the number of household members, having a household member at home on a typical weekday, and being a renter are positively related to combined electricity-natural gas EUI, age of the responding householder and housing unit type (single-family detached) are negatively related to the outcome variable. Households located in the midwest and south census regions are associated with lower combined electricity-natural gas EUI than those in the northeast.

Summary and conclusion

This study examined the impacts of class status (income), race, and gender, along with their intersections on residential energy efficiency inequality, measured by disparities in EUI (energy use intensity). In terms of energy efficiency, are lower-income, African American, and female-headed households more likely to be disadvantaged? Informed by the intersectionality literature, we took the analysis further by examining the extent to which the pairwise intersections of these variables condition their relationships with residential sector EUI. We note that our summary and concluding comments here are based on the full models (that is, the models that control for the impacts of conservation behavior and several statistical control variables).

The results in this study show, quite interestingly, that residential energy efficiency inequality is shaped by the intersections of race and income and race and gender. In the full electricity model (Table 4, model 3), residential EUI is impacted by the intersection of race and gender. While African American households with responding householders identifying as females are associated with higher residential electricity EUI relative to White households, those with responding householders identifying as males are, surprisingly, associated with lower EUI. As observed earlier, higher EUI scores are indicative of inefficiency, all else being the same. This finding suggests a differentiation of disadvantage in the African American community: the disadvantage appears to be affecting only households in which the respondent identifies as female. For context, the electricity EUI model excluding pairwise interactions between class, race, and gender shows no significant difference between African American and White households, which suggests that the relationship may have been suppressed by the absence of race-gender interactions. The findings suggest that African American households in which the respondent identified as female are more likely to reside in residential units that are relatively not energy-efficient, all else being the same, making them more likely to be energy-burdened.

The results also show that the relationship between income and residential sector EUI is conditioned by race. In both the natural gas and combined electricity-natural gas models, the negative relationship between income and residential EUI is more substantial among African American households than White households. Turning to the relationship between race and residential EUI conditional upon income, these models (the natural gas and combined electricity-natural gas models) show that as an African American household's income increases, its energy use per square foot (i.e., EUI) decreases in tandem. These relationships suggest that higher-income African American households are more likely to seek energy-efficient homes and/or use energy-efficient appliances. In essence, energy efficiency inequality between White and African American households (see Reames, 2016) may be undergirded by income inequality. This further indicates that the energy-related disadvantages observed in the African American community are not isomorphic across income levels.

The findings in this study underscore the importance of considering the intersections of statuses in social inequality studies. Feminist and other scholars of intersectionality have argued this point theoretically and empirically for decades (Browne & Misra, 2003; Crenshaw, 1989, 1991; Nawyn, 2014; Sutton et al., 2018). As the results reported here, for instance, demonstrate, it cannot be assumed that all African American households are similarly energy burdened.

In the results section, we briefly discussed the relationships between our measures of conservation behavior and other control variables and residential sector EUI, so we do not intend to repeat that discussion here.

While this study contributes significantly to the literature on inequality related to energy consumption, we acknowledge one important limitation. It covers only the residential sector (buildings), which means that a complete picture is not offered of how income, race, and gender are related to energy efficiency inequality overall. In particular, the study does not cover a major area of energy use among U.S. households: transportation. In 2016, light vehicles, which represent the primary mode of transit for most American households, accounted for 58.5% of transportation energy use in the U.S. (Davis & Boundy, 2019). This is an area that ought to be addressed in future analysis of energy efficiency inequality among U.S. households.

In conclusion, this study shows that residential energy efficiency inequality is shaped, in part, by the intersections of race and gender and race and income. The results, in short, show that while African American households with respondents identifying as females fare worse than White households in terms of electricity use EUI, those with respondents identifying as male actually fare better. The relationship between being an African American household and residential energy use per square foot of home space (i.e., EUI) is mediated by income: as incomes rise, EUI for housing units occupied by African American households decreases.

Declarations

Conflict of interest The authors declare no competing interests.

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