Household Energy Burden Across the Income Distribution: Geographic Variation and Price Responsiveness

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Abstract

Residential energy costs consume a larger share of income for lower-income households than for higher-income ones, but the size of that gap varies considerably across the United States. Using Consumer Expenditure Survey microdata from 2005 through 2024 merged with state-level energy prices from the EIA State Energy Data System, I document residential energy burden across all nine U.S. census divisions and the income distribution for six fuels: electricity, natural gas, heating oil, propane, gasoline, and diesel. I also estimate price elasticities of demand by income decile for the three fuels with sufficient within-state price variation to support reliable estimation: electricity, natural gas, and gasoline. Energy burden declines sharply with income across all divisions and all six fuels. Price elasticities are inelastic throughout the income distribution. A statistically detectable income gradient in elasticity is present for natural gas and gasoline but not for electricity. For natural gas and gasoline, higher-income households are more price-responsive than lower-income ones. For electricity, price responsiveness does not vary systematically with income.

1. Introduction

This paper documents residential energy burden across U.S. census divisions and the income distribution, and estimates price elasticities of residential energy demand by income decile. A map of the divisions is shown in Figure 1. Income deciles divide households into ten equally sized groups ranked from lowest to highest income. The first decile contains the ten percent of households with the lowest incomes; the tenth contains the ten percent with the highest.

A household in the East and West South Central divisions with an income in the second decile spent roughly 15 cents of every dollar it earned on residential energy on average over the 2005 through 2024 period. A household in the same income decile in the West North Central or Middle Atlantic spent about 11 cents. At the top of the income distribution, both households spent roughly 2 to 3 cents of each dollar. These differences, documented across the income distribution and all nine U.S. census divisions over twenty years, are the focus of this paper.

Federal assistance programs such as the Low Income Home Energy Assistance Program (LIHEAP) direct billions of dollars annually toward households to assist in paying energy bills. The energy burden literature has grown substantially since the creation of LIHEAP in 1981. Drehobl, Ross, and Ayala (2020) provide the most comprehensive recent assessment, documenting that low-income households face energy burdens two to three times higher than the national median across 25 U.S. metropolitan areas, with the East South Central region having the highest share of highly burdened households at 38 percent. Bednar and Reames (2020) document the absence of formal federal recognition of energy poverty in the United States and argue that such recognition is a prerequisite for coordinated policy action. Work by Batlle, Heller, Knittel, and Schittekatte (2024) shows that LIHEAP funding formulas, largely unchanged since 1984, have become misaligned with the distribution of energy poverty.

The residential energy demand literature has produced substantial evidence on price elasticities, mostly using aggregated state or utility-level data. Espey and Espey (2004) meta-analyze 36 studies and report a mean short-run electricity price elasticity of approximately -0.37. Alberini, Gans, and Velez-Lopez (2011) use household-level panel data from approximately 50 U.S. metropolitan areas covering 1997 through 2007 and find natural gas elasticities between -0.69 and -0.57 and electricity price elasticities in the -0.67 to -0.86 range, noting that the electricity elasticity declines with income, though the authors describe the magnitude of this income difference as small. Miller and Alberini (2016) show that elasticity estimates are sensitive to data aggregation and price endogeneity, with these factors capable of altering estimates by 50 to 100 percent. The distributional consequences of energy pricing have received attention primarily in the context of rate design. Borenstein (2012) shows that increasing-block electricity tariffs in California produce modest redistribution toward low-income households relative to their efficiency cost. Borenstein and Davis (2012) find that natural gas rate structures are only mildly progressive because poor households tend to have larger families and lower household energy efficiency. Schulte and Heindl (2017) use German household microdata to estimate that low-income households have weaker electricity price responses than high-income households.

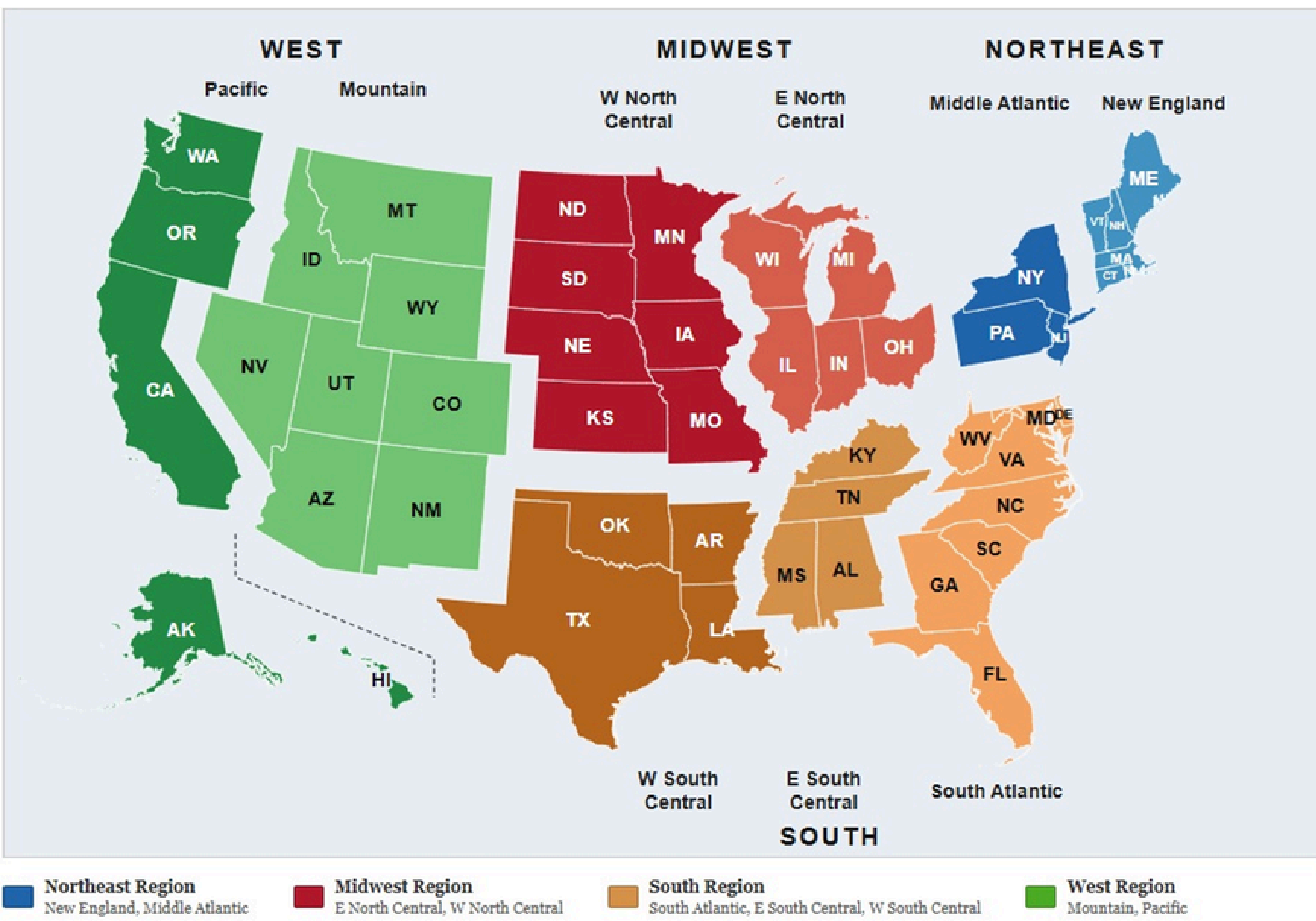
The existing literature shares a common limitation: studies focus on national averages, single fuel types, or short time windows, and few estimate how price responsiveness varies across the income distribution. This paper addresses those gaps.

Using the Consumer Expenditure Survey (CEX) from 2005 through 2024, merged with state-level residential energy prices from the EIA State Energy Data System (SEDS), I construct annual measures of household energy burden, defined as residential energy spending as a percentage of pre-tax income, for each of the nine census divisions by income decile. The descriptive analysis covers six residential fuels: electricity, natural gas, heating oil, propane, gasoline, and diesel. The elasticity analysis covers the three fuels for which within-state price variation is sufficient for reliable estimation after absorbing year fixed effects: electricity, natural gas, and gasoline.

Six findings stand out. First, energy burden is declining in income everywhere, but the gradient is steeper in some divisions than others, and the level of burden for low-income households varies substantially by geography. Second, in dollar terms households in New England spend the most on energy at the median, followed by the West and East South Central and Mountain divisions, while the West North Central, Middle Atlantic, and South Atlantic divisions spend the least. Third, for energy budget burden the pattern partially reverses: the East South Central and West South Central divisions have the highest burden, while New England, Middle Atlantic, and Pacific have the lowest because their higher incomes more than offset their dollar spending. Fourth, real household energy spending declined in all divisions over the sample period, a trend driven primarily by the sharp decline in natural gas prices after 2008. Fifth, price elasticities of demand are inelastic across all three fuels analyzed and across all income deciles. Sixth, the income gradient in elasticity differs by fuel. Natural gas elasticities tend to become more negative as income rises. Gasoline elasticities show a clear and steep decline with income. Electricity elasticities do not show a significant income gradient. The natural gas and gasoline patterns are consistent with higher-income households having greater discretionary energy use and substitution options available to them, while the absence of an electricity gradient is consistent with electricity having fewer income-dependent substitution options.

The remainder of this paper is organized as follows. Section 2 describes the data. Section 3 presents energy price trends by division. Section 4 shows spending patterns. Section 5 presents budget burden across the income distribution. Section 6 estimates price elasticities of household energy demand by income decile. Section 7 discusses what these patterns imply for policy design. Section 8 concludes.

Figure 1. U.S. Census Divisions and Regions



Source: U.S. Census Bureau

2. The Data

2.1 Consumer Expenditure Survey

The primary data source is the Consumer Expenditure Survey (CEX), conducted by the Bureau of Labor Statistics (BLS). The CEX collects detailed expenditure data from a nationally representative sample of U.S. households through quarterly interviews. I use the public-use FMLI (family characteristics and income) and MTBI (monthly expenditure) interview files for survey years 2005 through 2024, yielding a sample of approximately 490,000 household-year observations.

Energy expenditures are constructed from household-level spending on six fuel types: electricity, natural gas, heating oil, propane, gasoline, and diesel. Household income is defined as pre-tax. All dollar values are expressed in real 2024 dollars using the Bureau of Labor Statistics Consumer Price Index, All Urban Consumers (CPI-U).

Income deciles are constructed at the national level in each year, using CEX final interview weights to account for the survey's complex sampling design. The lowest income decile is excluded from the burden analysis due to data quality concerns. A substantial share of decile 1 households report expenditures that exceed reported income, suggesting either income underreporting or undocumented dissavings rather than genuine budget burden. The elasticity analysis in Section 6 uses a further restricted sample of households with observable Federal Information Processing Standards (FIPS) codes for state of residence, which account for approximately 88 percent of the full sample after excluding decile 1. State FIPS suppression by the BLS is discussed in Section 6.1.

2.2 Energy Prices

State-level residential energy prices come from the EIA State Energy Data System (SEDS). SEDS publishes annual state-level prices for electricity in cents per kilowatt-hour, natural gas in dollars per thousand cubic feet, heating oil, propane, gasoline, and diesel in dollars per gallon going back to the 1970s for all fuels except propane. Propane is available in SEDS only from 2010 forward. I merge these prices with CEX observations using the household's state identifier and survey year. Division-level price series in Figures 2 through 6 are weighted means of state prices with weights equal to the number of CEX observations from each state.

2.3 Energy Burden

Energy burden is defined as annual household energy spending divided by annual household income before taxes. Burden is computed separately for total energy and for each of the six fuels. Burden values are winsorized at [0, 1] for figures and tables to prevent a small number of extreme observations, typically households reporting low income relative to expenditure, from distorting the means.

Map figures (Figures 8 and 11) show weighted medians of spending and budget burden, respectively, pooled across 2020 through 2024 to reduce year-to-year sampling noise. Figures showing burden by decile and division (Figures 10 and 12 through 17) report weighted means pooled across 2005 through 2024 across the income distribution within each division.

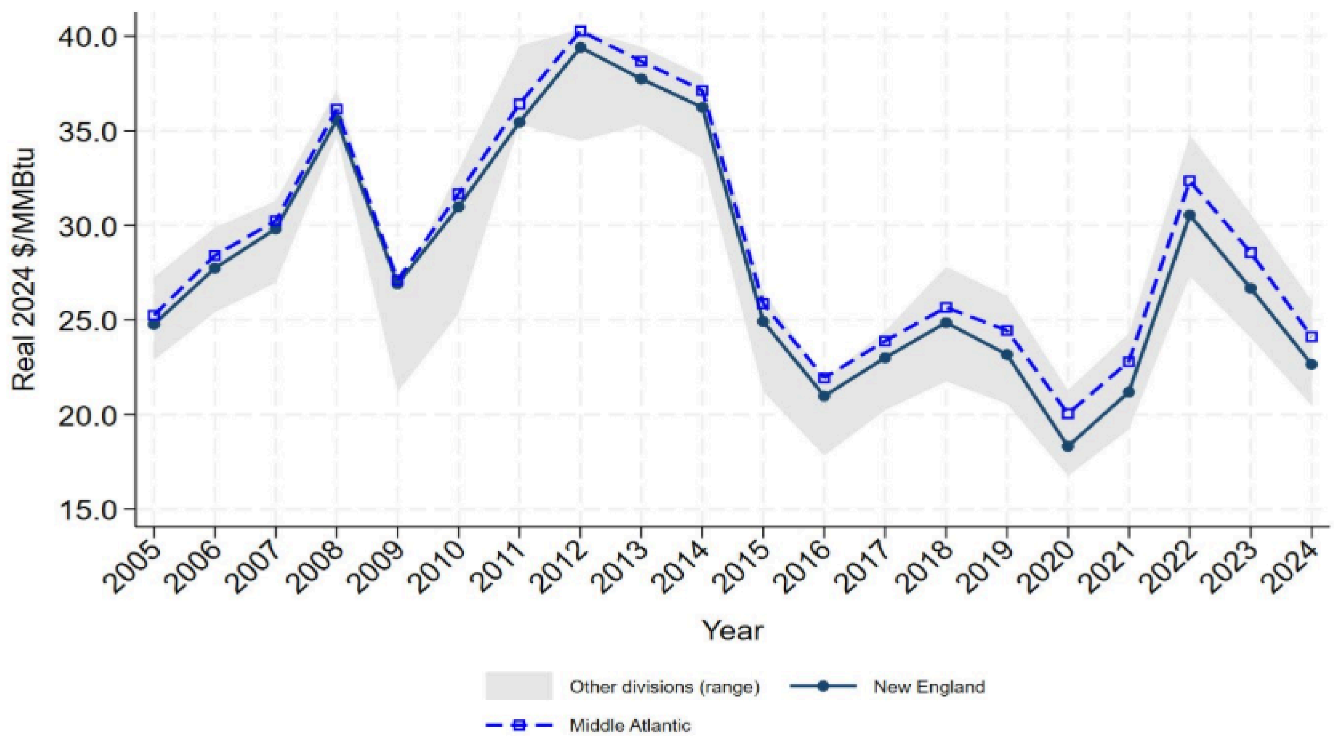
3. Energy Prices by Division

Figures 2 through 6 show the evolution of residential energy prices across the nine census divisions from 2005 through 2024. The fuels tell different stories.

3.1 Heating Oil

Heating oil prices (Figure 2) follow a pattern similar to gasoline because both fuels derive from crude oil refined in national and global markets. Prices peaked above $35 per million BTU in real 2024 dollars during the 2011 through 2014 period, fell to around $20 per MMBTU by 2016, and rose back toward $30 by 2022 before declining again. Geographic dispersion in heating oil prices is small relative to the time-series movement; the Middle Atlantic and New England divisions paid slightly more than other divisions throughout the sample period, but no division stands clearly apart from the rest. The narrow geographic dispersion turns out to matter for the elasticity analysis in Section 6.

Figure 2. Residential Heating Oil Price by Census Division, 2005-2024



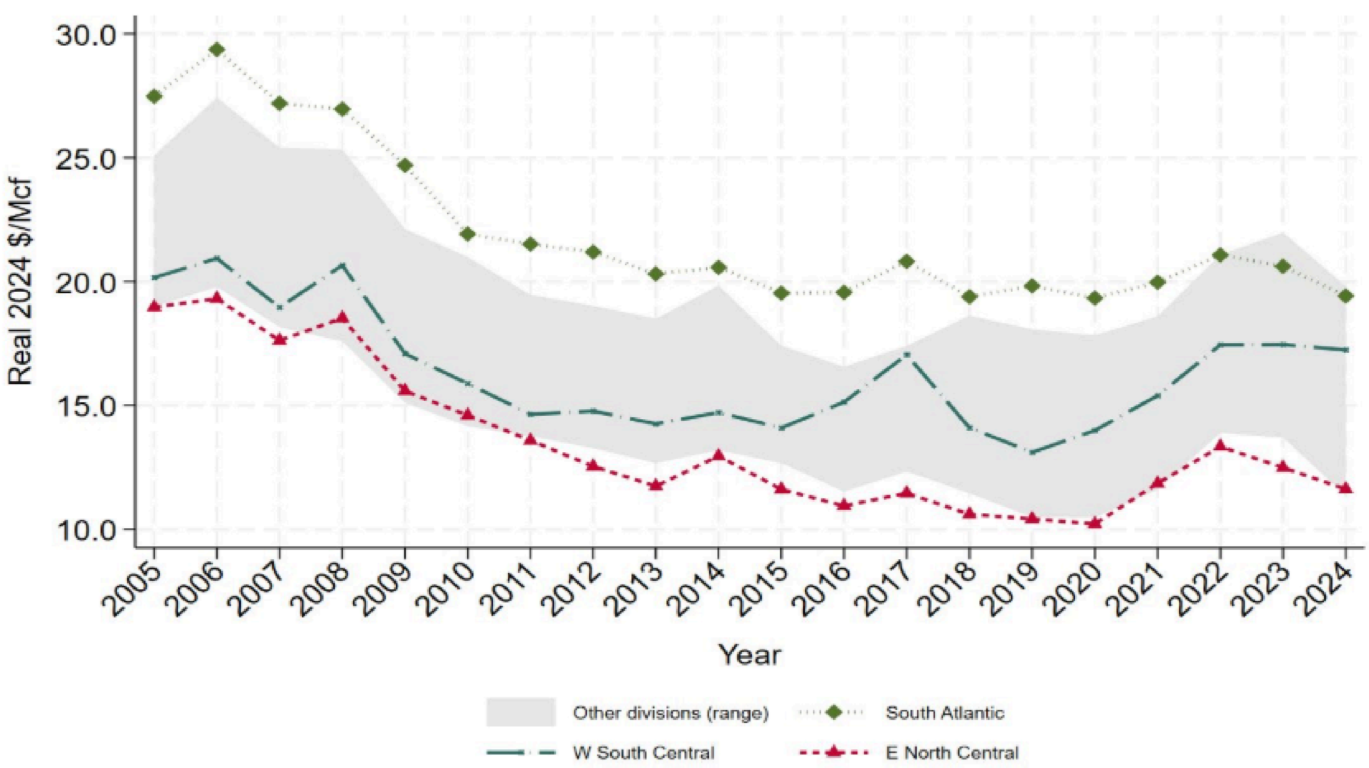
Source: EIA State Energy Data System. Division means weighted by CEX observations.

3.2 Natural Gas

Natural gas prices (Figure 3) tell a different story. In 2005 and 2006, prices varied substantially across divisions, with the South Atlantic paying the most, close to $30 per thousand cubic feet, and the East North Central and West North Central paying the least, around $18 to $20. The shale revolution changed levels but not rankings. Beginning around 2007, natural gas prices fell dramatically in all divisions. By 2020 all divisions were paying $10 to $20 per thousand cubic feet, down from $20 to $30 fifteen years earlier. The South Atlantic remained the most expensive division across the sample period, though its premium over other divisions narrowed. The East North Central and West North Central divisions paid the least, consistent with those regions' proximity to major production areas.

The price decline over this period represents one of the largest shifts in residential energy costs in recent U.S. history. For households and divisions that heat with natural gas, shown in Table 2, it meant a substantial real reduction in energy costs that shows up clearly in the spending data.

Figure 3. Residential Natural Gas Price by Census Division, 2005-2024



Source: EIA State Energy Data System. Division means weighted by CEX observations.

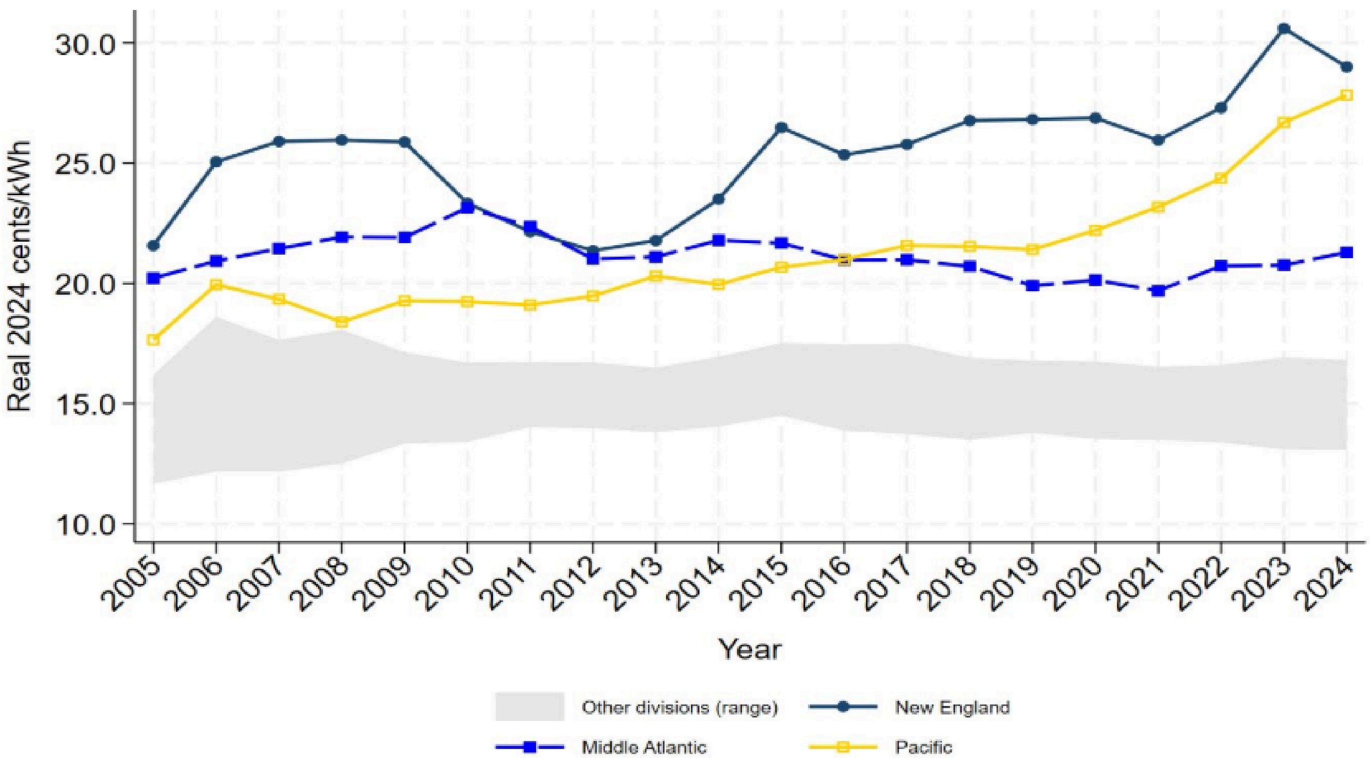
3.3 Electricity

Electricity prices (Figure 4) show yet another pattern, substantial geographic variation with relatively modest variation over time. New England paid more than any other division throughout the sample period, starting near 22 cents per kilowatt-hour in 2005 and reaching over 30 cents in 2023 before easing slightly in 2024. The Middle Atlantic was second highest until 2017, at roughly 20 to 22 cents per kilowatt-hour, when it was overtaken by the Pacific division. The remaining seven divisions clustered between 12 and

17 cents per kilowatt-hour for most of the sample period. The Pacific division showed the largest increase, rising from below 20 cents in the early years to nearly 28 cents per kilowatt-hour by 2024, converging toward New England levels.

The striking finding in Figure 4 is that the geographic spread in electricity prices dwarfs the time-series variation in any single division. A household in New England paid roughly twice as much per kilowatt-hour as a household in the West South Central or West North Central throughout the entire sample period. This geographic variation in electricity prices is the primary driver of the geographic variation in electricity burden documented in Section 5.

Figure 4. Residential Electricity Price by Census Division, 2005-2024

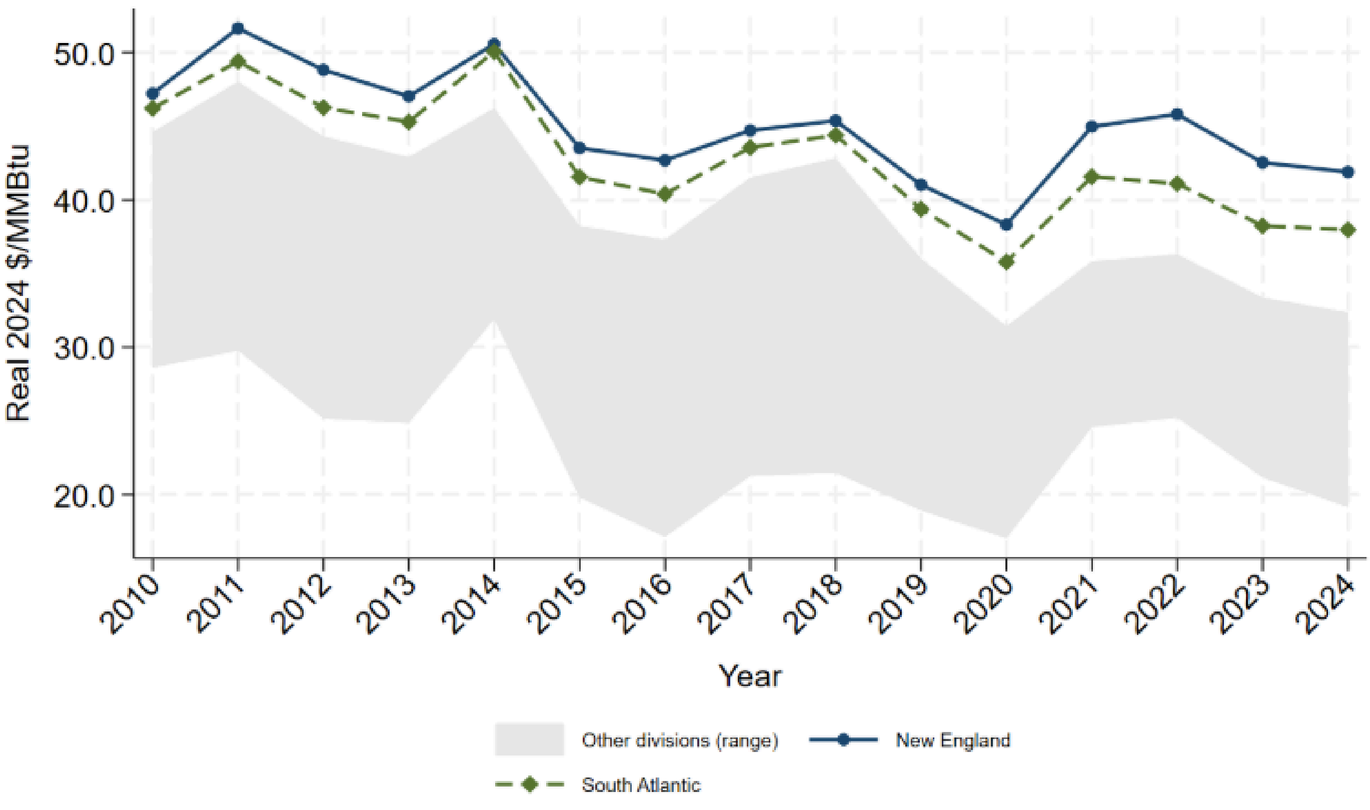


Source: EIA State Energy Data System. Division means weighted by CEX observations.

3.4 Propane

Propane prices (Figure 5) are available in SEDS only from 2010 forward. Prices peaked above $50 per million BTU in real 2024 dollars in the 2011 through 2014 period, fell toward $25 per MMBTU by 2020, and rose again through 2024. New England and South Atlantic have paid the highest propane prices throughout the period for which data are available with both standing notably above the other divisions.

Figure 5. Residential Propane Price by Census Division, 2005-2024



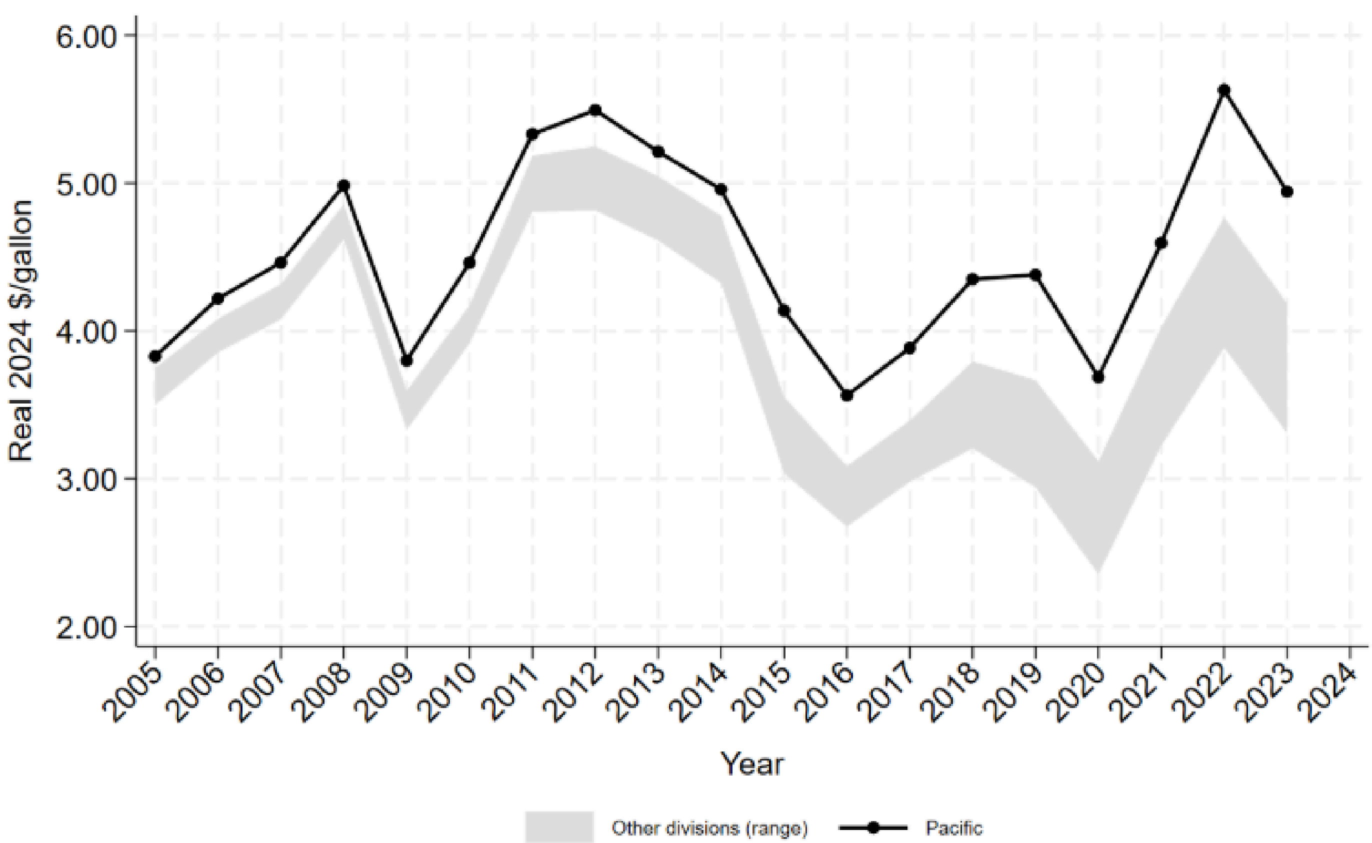
Note: State-level propane prices not available in SEDS before 2010.

Source: EIA State Energy Data System. State-level propane prices not available before 2010.

3.5 Gasoline

Gasoline prices (Figure 6) moved generally in parallel across regions, as would be expected for a fuel priced in a national market. The Pacific division consistently paid the most, reflecting California's higher energy taxes and environmental regulations. Pacific prices ranged from roughly $3.80 per gallon in 2005 to a peak above $5.60 per gallon in 2022 before falling back below $5.00 per gallon in 2023. The remaining eight divisions tracked closely together, with prices roughly $0.80 to $1.50 per gallon below Pacific. All divisions showed a similar pattern: a peak around 2012 near $5.00 per gallon in real 2024 dollars, a sharp decline to the $2.70 to $3.20 range by 2016, relative stability through 2019, a COVID-era trough in 2020, and a sharp spike in 2022.

Figure 6. Retail Gasoline Price by Census Division, 2005-2023



Source: EIA State Energy Data System. Division means weighted by CEX observations. 2024 gasoline price data not yet finalized at the time of analysis.

4. Household Energy Spending

Figure 7 shows median household total energy spending in real 2024 dollars by division from 2005 through 2024, pooling deciles 2 through 10. Total energy spending is the sum of household spending on all six fuels.

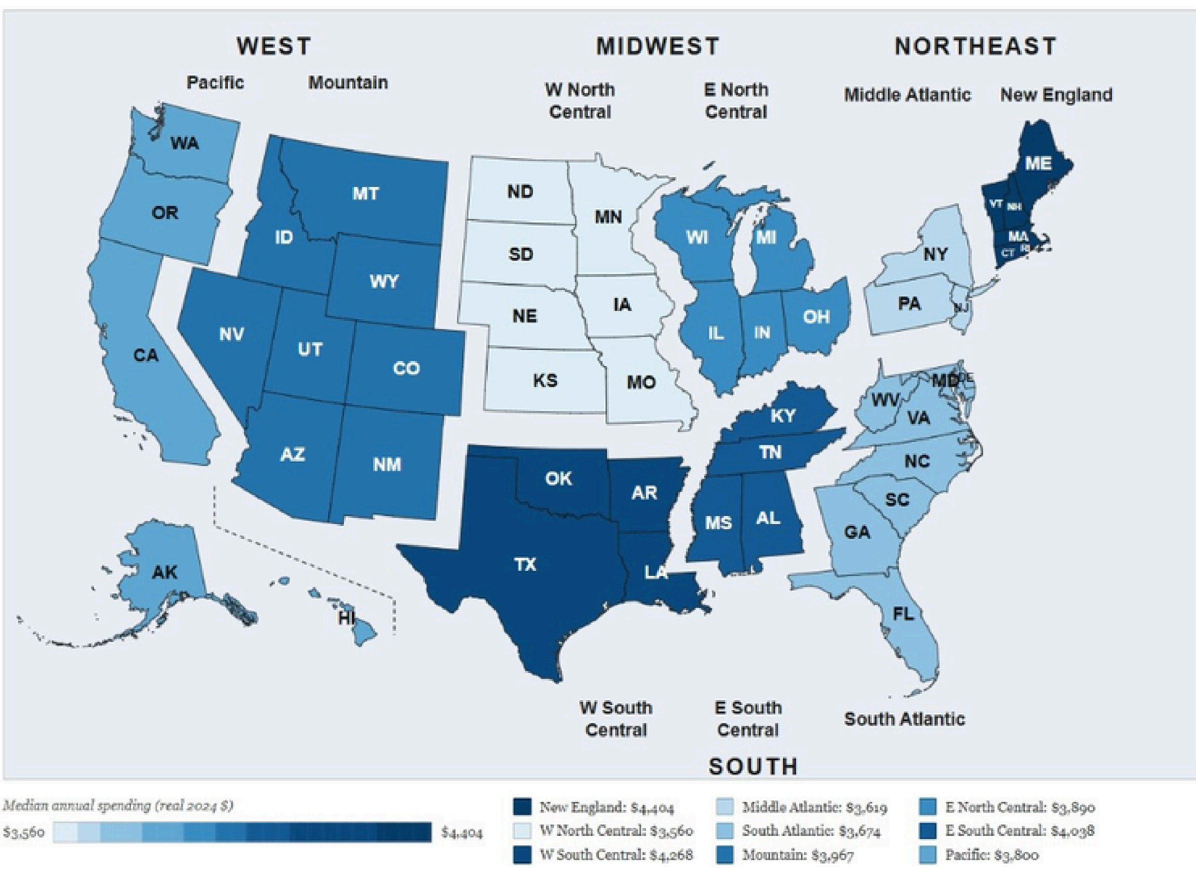
Figure 7. Median Household Total Energy Spending by Census Division, 2005-2024

Real 2024 dollars, deciles 2-10. Source: CEX. Median computed with CEX final interview weights.

Two features dominate the spending picture. First, spending peaked around 2008 and again around 2012, then fell substantially. By 2020, median spending in most divisions had fallen to levels not seen since before 2005. The decline was roughly $1,000 to $1,500 per household in real terms in many divisions, a reduction of 25 to 35 percent from peak levels. The dominant driver of this decline was falling natural gas prices. Divisions where households rely heavily on natural gas for heating, particularly the East North Central, West North Central, and Middle Atlantic divisions, as shown in Table 2, saw the largest spending reductions. Second, spending increased somewhat after 2020, with most divisions returning to roughly $3,500 to $4,500 per year by 2023 and 2024 in real terms. New England has had the highest median spending throughout the sample period, while the West North Central has had the lowest.

Figure 8 shows the cross-sectional pattern for the 2020 through 2024 period. New England had the highest median spending at $4,404 per year, followed by the West South Central ($4,268), East South Central ($4,038), and Mountain ($3,967) divisions. The West North Central division had the lowest median spending ($3,560), followed by Middle Atlantic ($3,619) and South Atlantic ($3,674). The $844 gap between the highest and lowest spending divisions is not trivial, but it is considerably smaller than might be expected given the electricity price differences shown in Figure 4.

Figure 8. Median 2020-2024 Annual Household Residential Energy Spending by Census Division



Real 2024 dollars, pooled 2020-2024, income deciles 2-10. Source: CEX. Median computed with CEX final interview weights.

Table 1. Mean Annual Residential Energy Spending by Census Division (Real 2024 Dollars)

Division	Income	Electricity	Nat. Gas	Heat. Oil	Propane	Gasoline	Diesel	N
New England	$137,423	$1,779	$573	$505	$116	$2,256	$7	4,335
Pacific	$131,403	$1,479	$446	$15	$36	$2,670	$8	16,526
Middle Atlantic	$124,488	$1,495	$706	$190	$50	$1,928	$8	9,284
Mountain	$115,238	$1,572	$467	$6	$18	$2,661	$10	6,738
South Atlantic	$109,912	$1,722	$259	$19	$46	$2,251	$9	16,848
W North Central	$109,646	$1,350	$626	$11	$48	$2,122	$11	5,702
E North Central	$109,583	$1,386	$729	$16	$43	$2,306	$10	10,531
W South Central	$100,411	$1,951	$299	$3	$24	$2,546	$8	8,009
E South Central	$95,526	$1,835	$283	$4	$48	$2,492	$12	3,644

Notes: Pooled 2020-2024, income deciles 2-10. Sorted by median household income (descending). All values in real 2024 dollars. Spending columns show mean annual spending by fuel among households reporting positive expenditure on that fuel. Heating oil and propane spending appears as zero or near zero in divisions where almost no households use those fuels (e.g., heating oil in W South Central, propane in Mountain). N is the count of household-year observations in the division. Source: Consumer Expenditure Survey (BLS), 2020-2024.

Table 2. Share of Households Reporting Positive Energy Spending by Census Division

Division	Electricity	Nat. Gas	Heat. Oil	Propane	Gasoline	Diesel
New England	83.7%	40.9%	17.0%	5.8%	83.4%	20.4%
Pacific	84.0%	56.4%	0.5%	3.0%	84.7%	21.7%
Middle Atlantic	83.5%	58.6%	5.3%	3.3%	75.7%	17.6%
Mountain	85.3%	60.5%	0.3%	3.9%	86.6%	26.7%
South Atlantic	87.1%	28.4%	0.8%	2.8%	85.6%	19.8%
W North Central	86.9%	66.9%	0.2%	4.0%	86.9%	25.0%
E North Central	87.5%	70.5%	0.5%	3.5%	85.1%	21.1%
W South Central	87.5%	39.3%	0.2%	3.2%	87.1%	16.8%
E South Central	88.9%	38.9%	0.3%	5.1%	87.2%	23.8%

Notes: Pooled 2020-2024, income deciles 2-10. Sorted by median household income (descending). Figures are weighted shares using CEX final interview weights. A household is counted as a user of a fuel if it reports positive expenditure on that fuel in the CEX interview. Households whose energy costs are bundled into rent or otherwise not separately reported will appear as non-users. Income decile 1 excluded. Source: Consumer Expenditure Survey (BLS), 2020-2024.

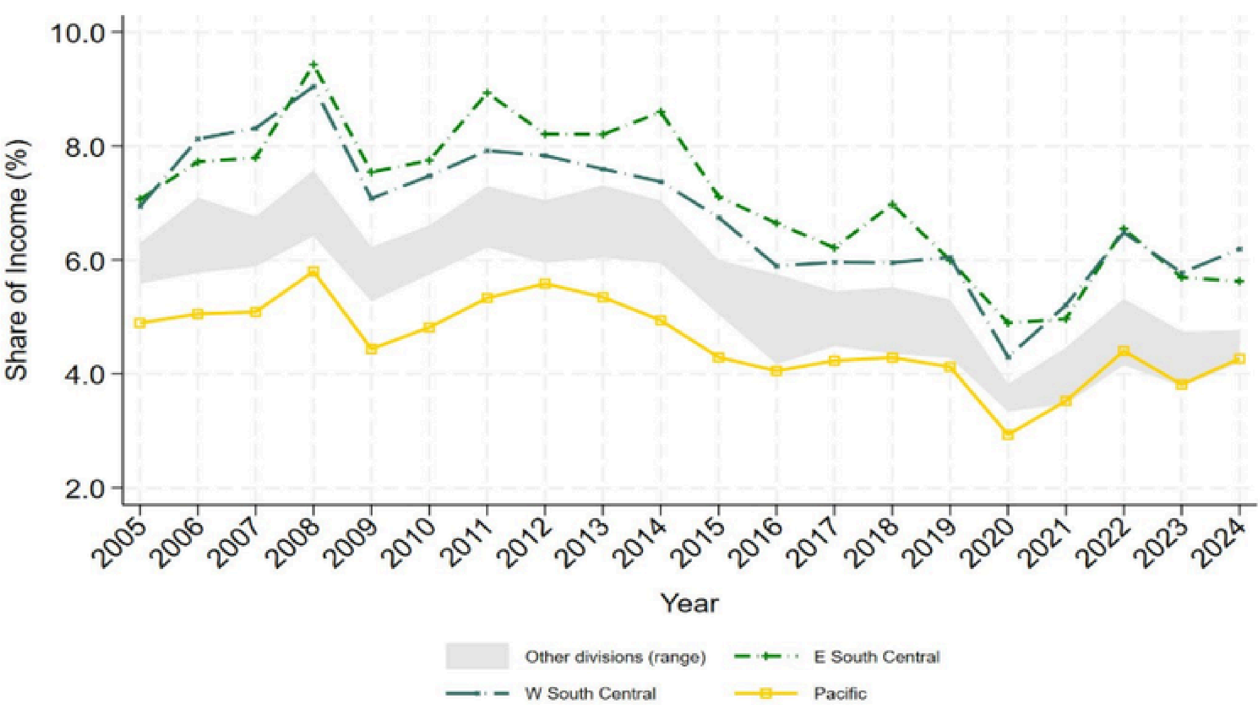
5. Energy Budget Burden

5.1 Total burden

Figure 9 shows median total energy burden by division from 2005 through 2024, weighted using CEX final interview weights. The time-series pattern parallels the spending pattern in Figure 7. Burden fell substantially from peaks of around 8 to 9 percent in the East and West South Central divisions during the 2008 through 2014 period to roughly 5 to 6 percent by 2020, before partially rebounding through 2024. The decline reflects both falling natural gas prices over this period and rising household incomes.

The geographic pattern is also clear. The East and West South Central divisions had the highest median burden throughout the sample period, sitting visibly above the other divisions. The Pacific division had the lowest, sitting below the range of all other divisions for most of the sample. The remaining six divisions formed a band running roughly between 4 and 7 percent of income, with no individual division standing notably apart from the others. The 2020 trough is visible as a sharp convergence in burden levels across all divisions, driven by the combination of energy price collapse and stimulus payments that raised reported income. Burden levels rose somewhat after 2020 as energy prices rebounded.

Figure 9. Median Total Energy Burden by Census Division, 2005-2024

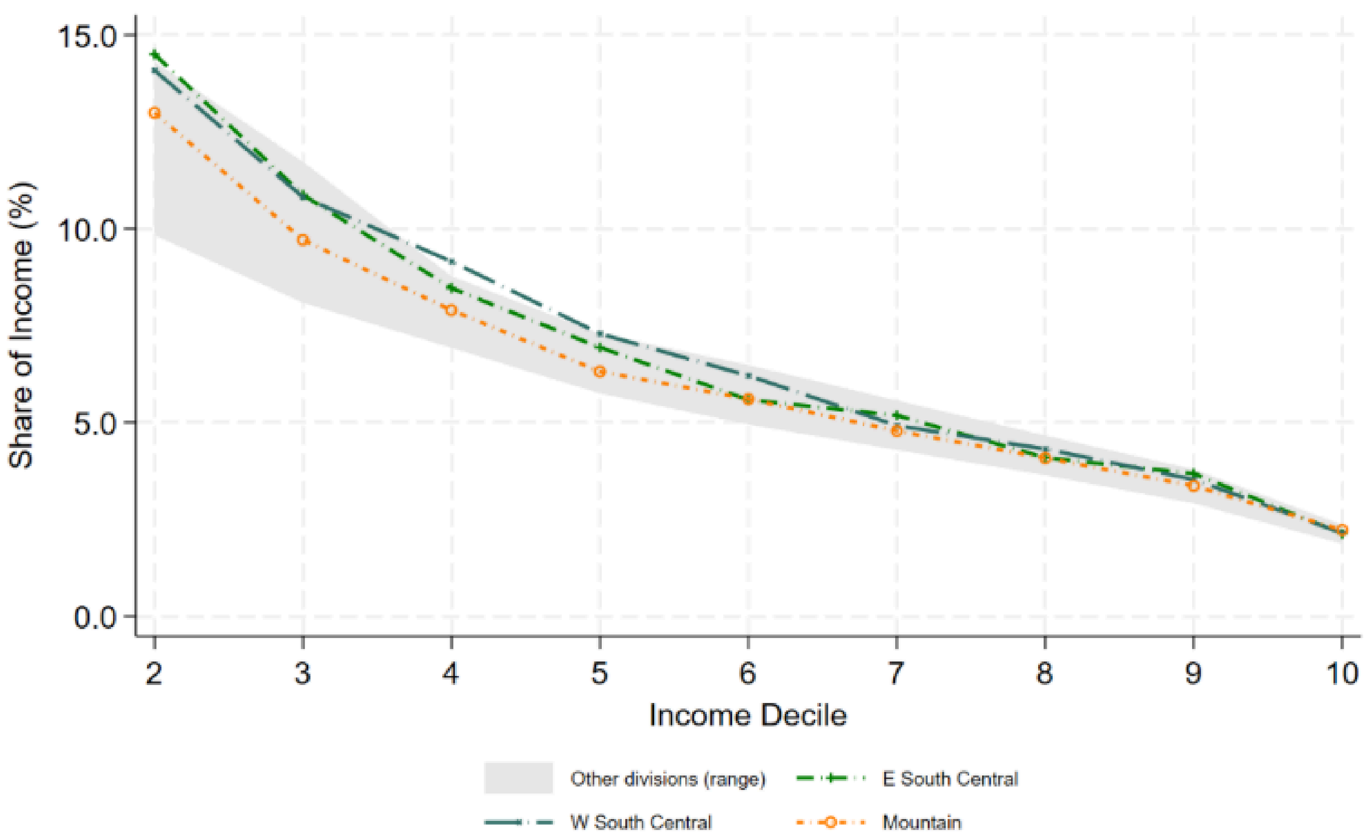


Share of household income before taxes, deciles 2-10. Source: CEX 2005-2024. Median computed with CEX final interview weights. Energy burden = total residential energy expenditure / household income before taxes.

Figure 10 shows mean total energy burden by income decile and census division pooled across 2005 through 2024. The pattern is consistent across all nine divisions: burden declines sharply with income. Households in the second income decile, the lowest included in the analysis, spent between roughly 11 and 15 percent of pre-tax income on residential energy, depending on division. By the tenth decile, that share had fallen to between 2 and 3 percent in all divisions.

The divisions that stand out most clearly are the East and West South Central, whose second-decile households reached 15 percent burden, the highest of any division. Mountain was third highest at 13.5 percent. The South Central pattern reflects a combination of heavy energy use for cooling, and incomes that are lower than the national average. The Mountain division's elevated burden reflects similar factors, with long driving distances and substantial heating and cooling loads.

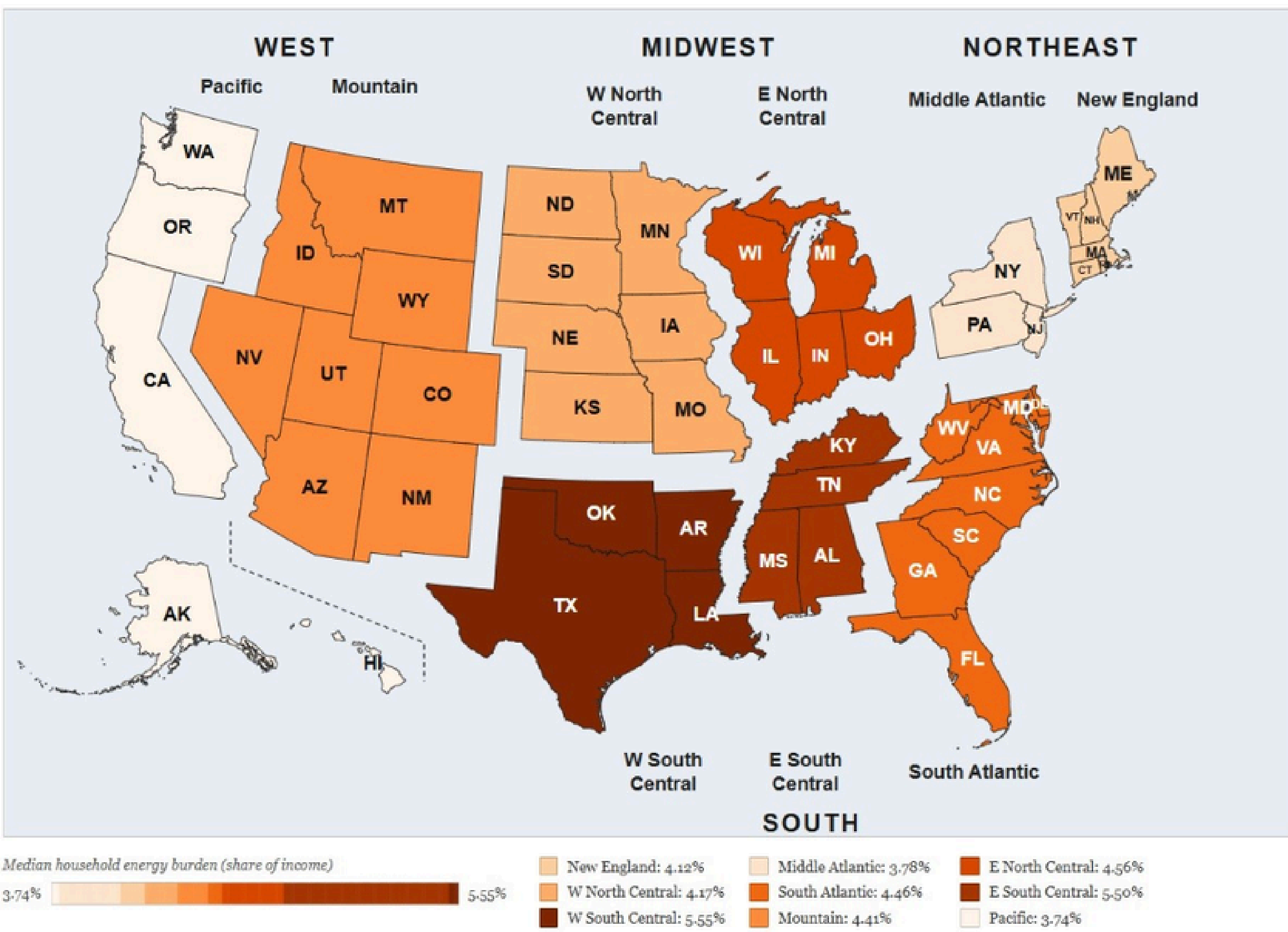
Figure 10. Total Energy Burden by Income Decile and Division, Pooled 2005-2024



Source: CEX 2005-2024. Decile 1 excluded.

Figure 11 maps the median burden by division for the pooled 2020 through 2024 period. The geographic pattern that emerged from the time series in Figure 9 holds in this snapshot: the East and West South Central divisions have the highest energy budget burdens, while Pacific and Middle Atlantic have the lowest. East and West South Central have median burdens of 5.50 and 5.55 percent of income, respectively, followed by Mountain (4.41 percent) and East North Central (4.56 percent). Pacific is lowest at 3.74 percent, followed by Middle Atlantic at 3.78 percent and New England at 4.12 percent. The remaining divisions fall between 4.17 and 4.46 percent.

Figure 11. Median Residential Energy Budget Burden by Census Division, 2020-2024

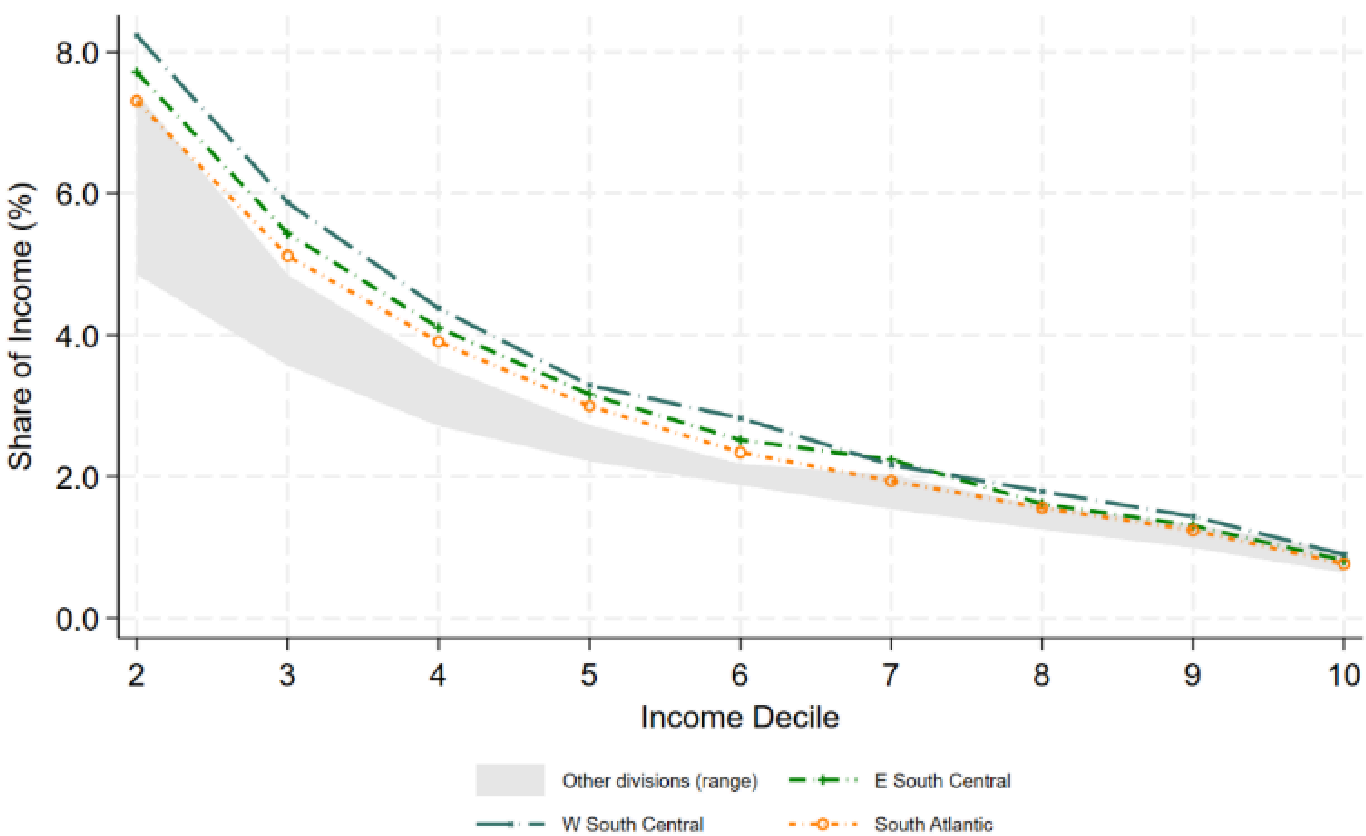


Share of household income before taxes, pooled 2020-2024, income deciles 2-10. Source: CEX. Median computed with CEX final interview weights. Energy burden = total household energy expenditure / household income before taxes. Winsorized at [0, 1].

5.2 Electricity burden

Figure 12 shows electricity burden by decile and division pooled across 2005 through 2024. The East and West South Central divisions had the highest electricity burdens at the bottom of the income distribution, with second-decile households spending above 7 percent of income on electricity alone. The South Atlantic followed at just under 7 percent. These three divisions sit visibly above the other six. New England, Middle Atlantic, Pacific, and the North Central divisions had electricity burdens for second-decile households in the 4 to 5 percent range, despite New England and Pacific paying the highest electricity prices per kilowatt-hour. The explanation is that New England and Pacific households tend to heat primarily with non-electric fuels and live in milder summer climates that limit cooling needs. The result is that high price multiplied by low quantity produces a burden lower than in divisions with cheaper electricity but higher consumption.

Figure 12. Electricity Budget Burden by Income Decile and Division, Pooled 2005-2024

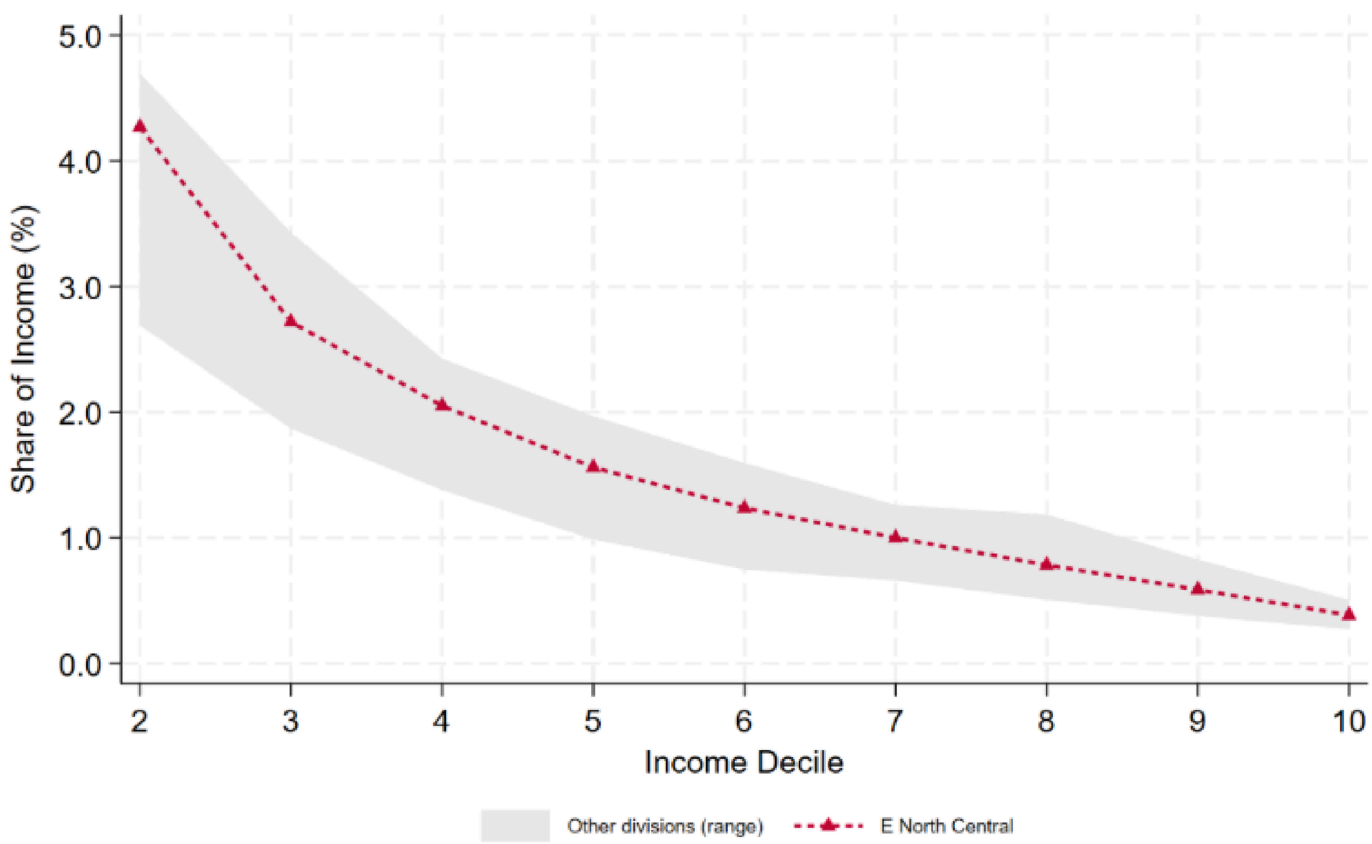


Source: CEX 2005-2024. Decile 1 excluded.

5.3 Natural gas burden

Figure 13 shows natural gas burden by decile and division pooled across 2005 through 2024. The natural gas picture is more complex than the other fuels because natural gas use varies dramatically by climate zone and because some divisions, such as the South Atlantic, rely much less on natural gas for heating than others, as Table 2 documents. The highest second-decile burden is in East North Central where households spent about 2.5 percent of income on natural gas alone. The pattern reflects the underlying climate and fuel mix: cold-climate divisions where natural gas is the dominant heating fuel versus warm-climate divisions with little gas heating.

Figure 13. Natural Gas Budget Burden by Income Decile and Division, Pooled 2005-2024

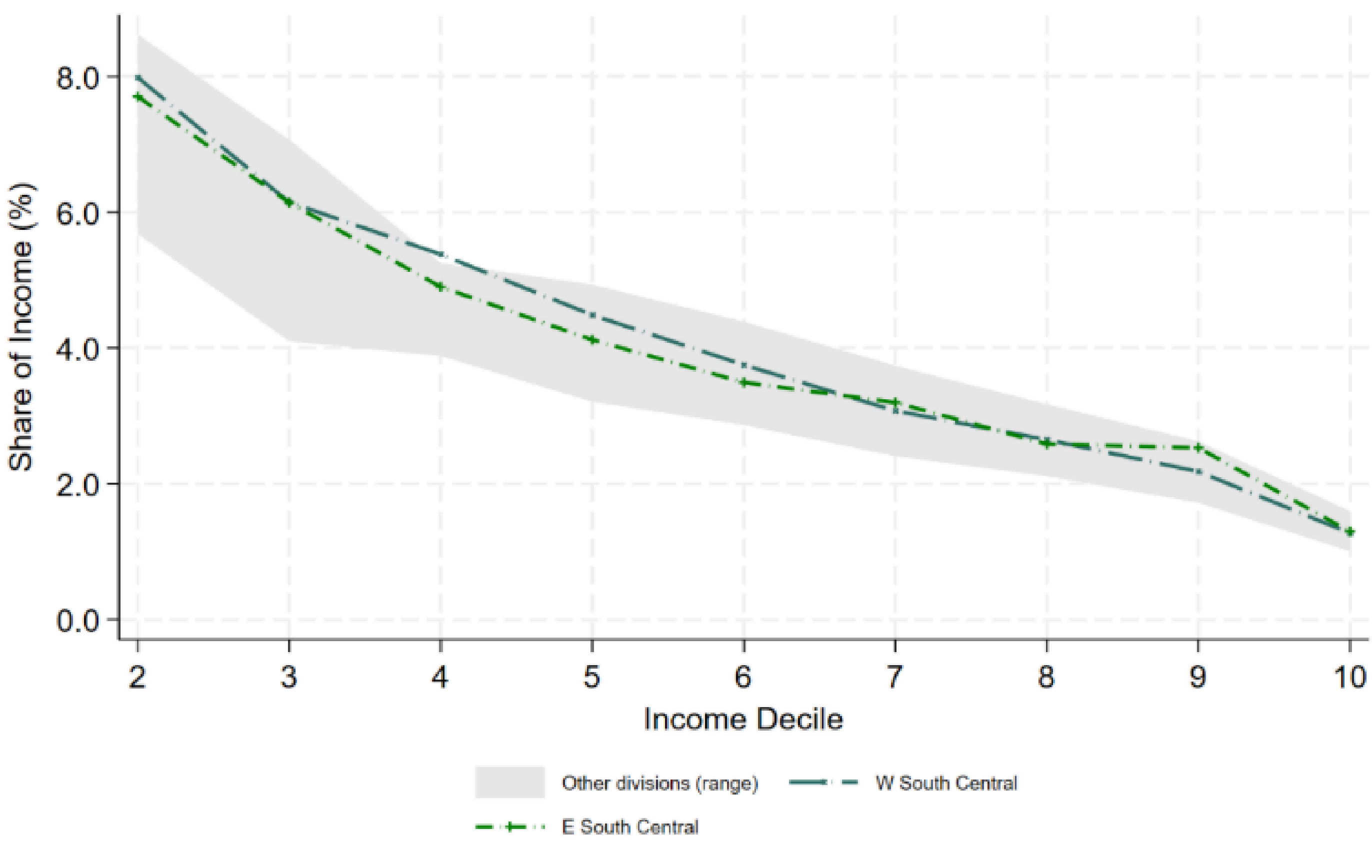


Source: CEX 2005-2024. Decile 1 excluded.

5.4 Gasoline burden

Figure 14 shows gasoline burden by decile and division pooled across 2005 through 2024. Gasoline burden declines with income across all divisions, with the largest differences at the bottom of the distribution. At the second decile, households in West and East South Central divisions spend approximately 8.0 and 7.7 percent of income on gasoline, respectively, reflecting long driving distances and lower incomes than the national average. At the top of the income distribution, gasoline burden converges across all divisions to between 1 and 1.5 percent.

Figure 14. Gasoline Budget Burden by Income Decile and Division, Pooled 2005-2024

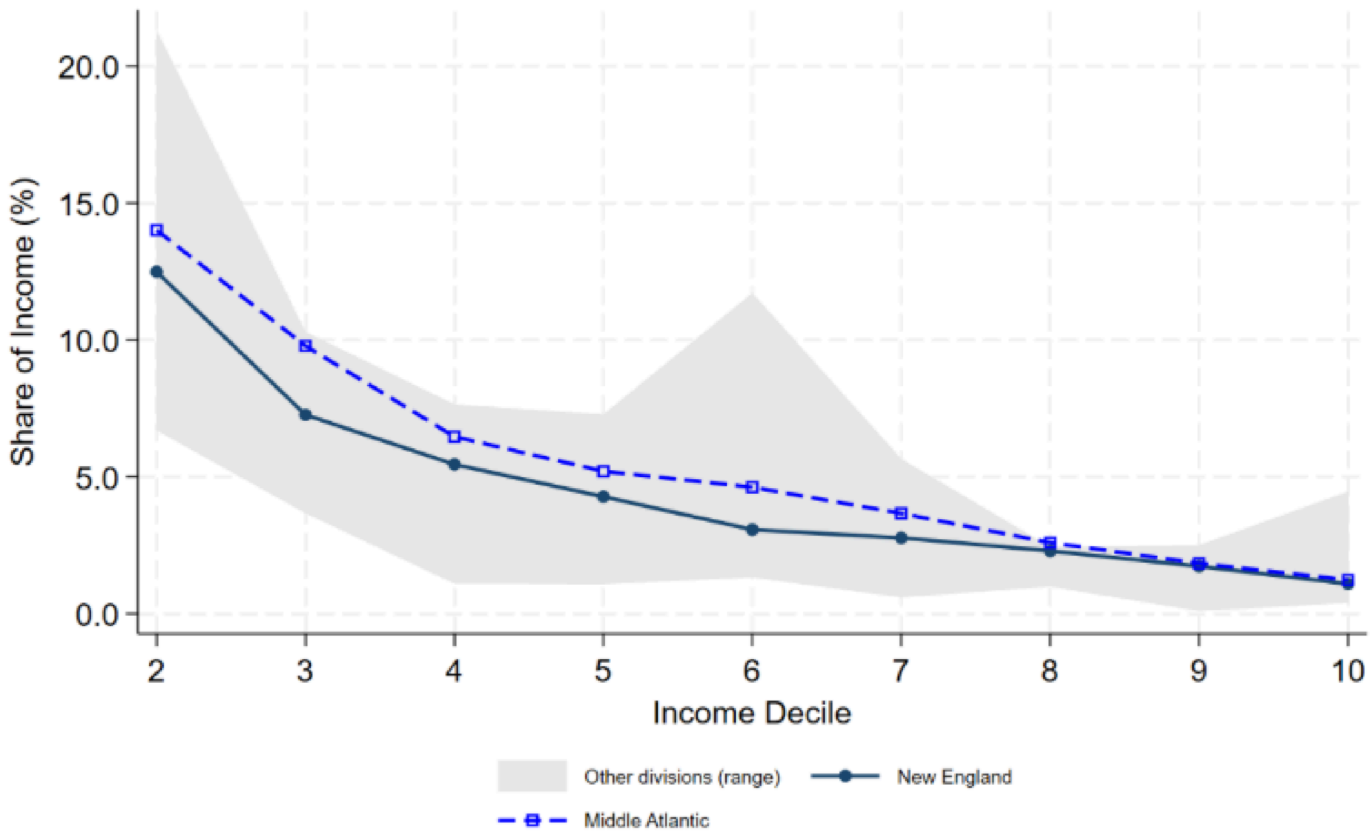


Source: CEX 2005-2024. Decile 1 excluded.

5.5 Heating oil burden

Figure 15 shows heating oil burden among households reporting positive heating oil expenditure, by decile and division. Heating oil use is heavily concentrated in the New England and Middle Atlantic divisions, with very small user shares elsewhere (see Table 2). Among heating oil users, the burden pattern is declining in income. At the bottom of the income distribution, heating oil-using households in New England and Middle Atlantic faced conditional burdens of 12 to 14 percent of income, which when added to their natural gas and electricity burdens push their total residential energy burden close to or above the levels seen in the South Central divisions despite higher division-average incomes.

Figure 15. Heating Oil Budget Burden by Income Decile and Division, Pooled 2005-2024

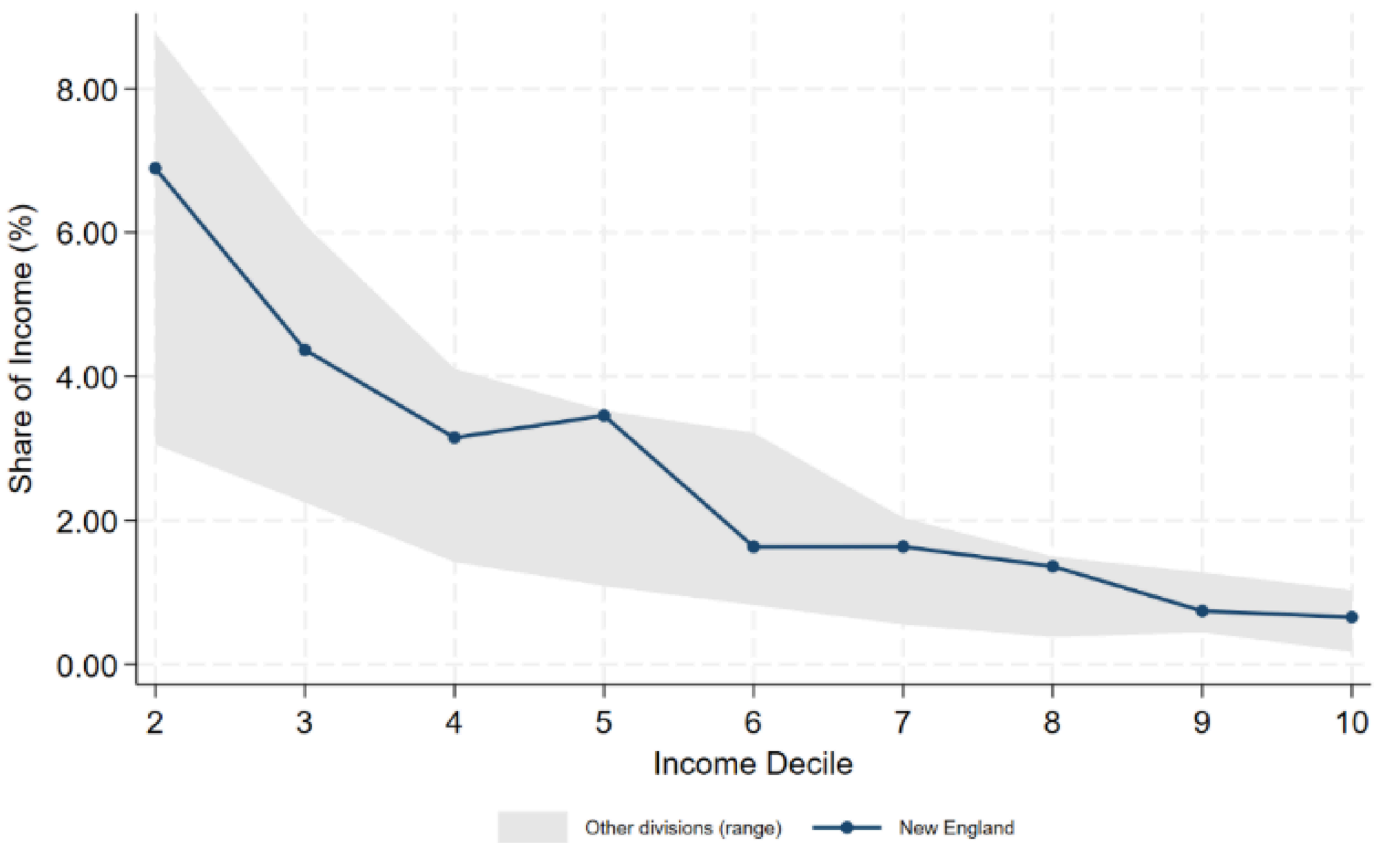


Source: CEX 2005-2024. Conditional on positive heating oil expenditure. Decile 1 excluded.

5.6 Propane burden

Figure 16 shows propane burden among households reporting positive propane expenditure, by decile and division. Propane use is more dispersed geographically than heating oil but tends to be used in rural areas where natural gas distribution is limited. The New England, East South Central, West North Central, and Mountain divisions have the largest propane-using populations . Among propane users, New England sits near the top of the distribution at the bottom of the income distribution, with second-decile households facing burdens of approximately 6.9 percent. The other divisions show wide variation at decile 2, with the band spanning roughly 3 to 9 percent, reflecting the small sample sizes and diverse use patterns among propane users across divisions. All divisions converge toward lower burden levels as income rises .

Figure 16. Propane Budget Burden by Income Decile and Division, Pooled 2010-2024

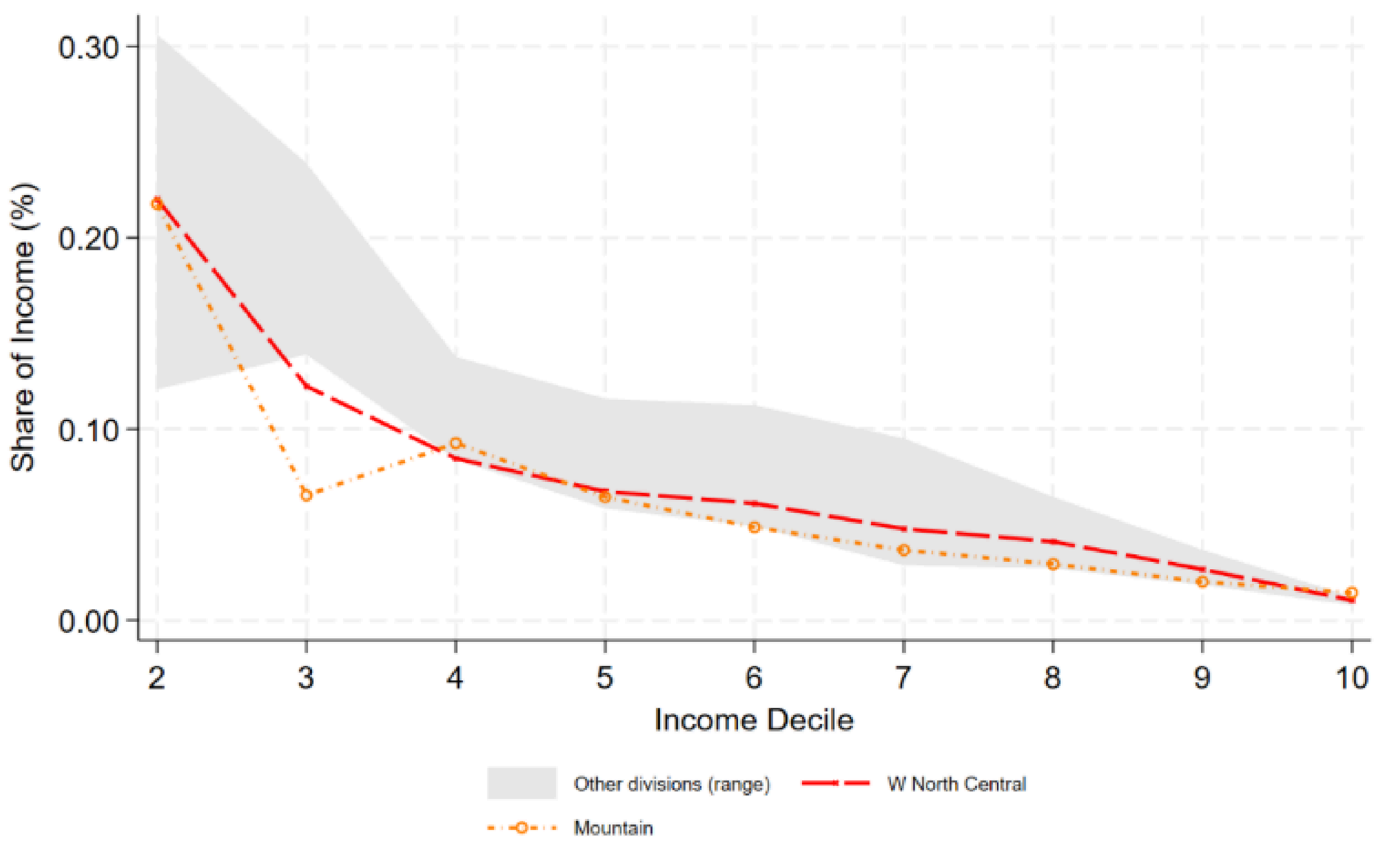


Source: CEX 2010-2024. Conditional on positive propane expenditure. Decile 1 excluded. Propane prices not available in SEDS before 2010.

5.7 Diesel burden

Figure 17 shows diesel burden among households reporting positive diesel expenditure, by decile and division. Reported diesel expenditure in the CEX is concentrated among households in rural areas, particularly in the West North Central, Mountain, and West South Central divisions, where farm and ranch operations are common. Diesel burden is small across all divisions and income deciles, reaching at most roughly 0.3 percent of income at the bottom of the distribution. Given the small number of residential diesel users in the CEX, these estimates should be interpreted with caution.

Figure 17. Diesel Budget Burden by Income Decile and Division, Pooled 2005-2024



Source: CEX 2005-2024. Conditional on positive diesel expenditure. Decile 1 excluded.

6. Price Elasticity of Residential Energy Demand

6.1 Estimation strategy

The burden patterns documented in Sections 3 through 5 establish that energy costs consume a disproportionate share of income for lower-income households and that the pattern varies across fuels and census divisions. A natural follow-on question is how households respond to price changes. If demand is highly elastic, price increases will be offset by reduced consumption, limiting the burden impact. If demand is inelastic, price increases tend to translate into higher expenditure, amplifying the burden effects the descriptive analysis documents. This section estimates price elasticities of residential energy demand by national income decile to address that question.

I estimate price elasticities using the log-log model shown in Equation 1.

$$\ln E_{i,t} = \beta_0 + \beta_1 \ln(P_{s,t}) + \beta_2 \ln(Y_{i,t}) + X_{i,t}\gamma + \mu_s + \tau_t + \varepsilon_{i,t}$$

where $E_{i,t}$ is annual real energy expenditure for household i in year t, $P_{s,t}$ is the real state-level residential price for the relevant fuel in state s and year t from the EIA State Energy Data System, $Y_{i,t}$ is real pre-tax income for household i in year t, $X_{i,t}$ is a vector of control variables, μ_s is a state fixed effect, and τ_t is a year fixed effect. The coefficient β_1 is the price elasticity of expenditure. Because expenditure equals price times quantity, the conventional price elasticity of quantity demanded equals β_1 minus 1. Regressions are estimated separately for each national income decile and each fuel type. Standard errors are clustered at the state level.

State fixed effects absorb time-invariant differences across states in energy consumption patterns, climate, housing stock, and regulatory environment. Year fixed effects absorb national trends in energy prices and macroeconomic conditions. Identification comes from within-state over time variation in prices after removing common national trends.

The elasticity analysis is restricted to electricity, natural gas, and gasoline. I investigated heating oil and propane initially but excluded both because as refined products priced largely off national and global crude oil markets, state-level retail prices follow a common time-series pattern across the country, leaving insufficient within-state variation to support reliable estimation once year fixed effects are applied. Diesel is omitted from the elasticity analysis as well because the residential diesel sample in the CEX is small and concentrated among households whose diesel use can reasonably be attributed in some part to farm and work vehicles rather than residential energy services. The descriptive analysis in Sections 3 through 5 covers all six fuels.

The estimation sample is restricted to households with observable state FIPS codes, which account for approximately 88 percent of the full sample. To protect respondent anonymity, state FIPS codes are suppressed by the Bureau of Labor Statistics for approximately 16 percent of second-decile households and 5 percent of tenth-decile households, a pattern of non-random suppression concentrated at the bottom of the income distribution. Inverse probability weights correct partially for this non-random suppression by upweighting households from income deciles and divisions where suppression is more common. Each observation receives a weight equal to the standard CEX survey weight divided by the fraction of households in that decile-division cell with observable state identifiers.

I estimate four specifications that vary along two dimensions: inverse probability weighting and household characteristic controls for family size, owner-occupancy status, urban residence, number of vehicles, and number of rooms. Models 1 and 3 do not include household characteristic controls beyond log income and the fixed effects. Models 2 and 4 include household characteristic controls. Models 1 and 2 use the standard CEX survey weights. Models 3 and 4 use the inverse probability weights. Model 4, the IPW-weighted specification with full household controls, is the main specification, with Models 1 through 3 serving as robustness checks. The four models together demonstrate that the main results are not sensitive to either the weighting correction or the inclusion of household controls.

6.2 Results

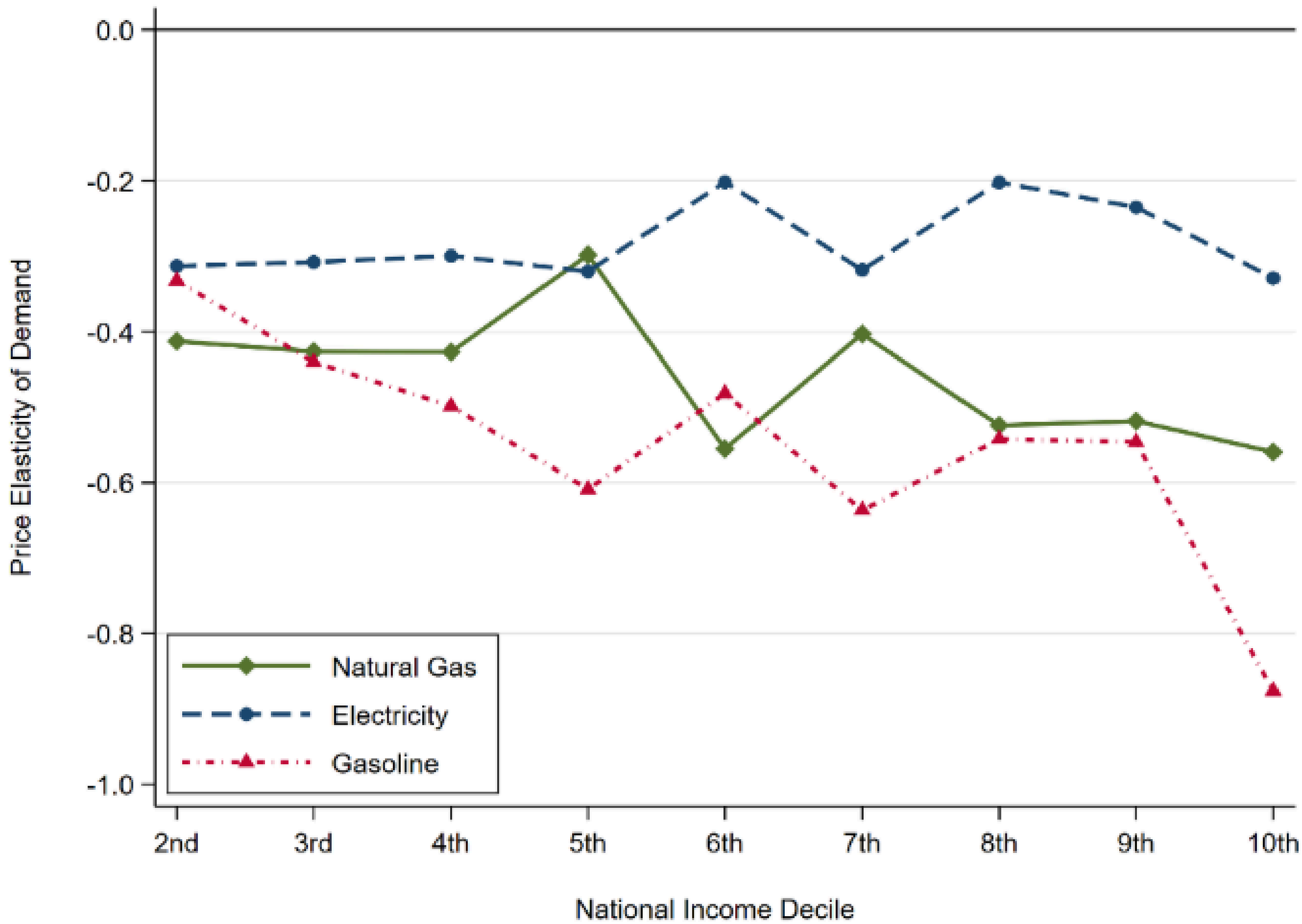
Table 3 reports price elasticity estimates by fuel type and national income decile across all four model specifications. All estimates are expressed as conventional price elasticities of quantity demanded, equal to the expenditure elasticity minus one. Figure 18 plots the main specification (Model 4) estimates by income decile across all three fuels. All three fuels show inelastic demand throughout the income distribution, with quantity elasticities between zero and negative one in every decile and model.

Table 3. Price Elasticities of Residential Energy Demand by Income Decile and Model Specification

	Electricity				Natural Gas				Gasoline			
Income Decile	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**	**(1)**	**(2)**	**(3)**	**(4)**
2	-0.298* (0.166)	-0.308* (0.164)	-0.307* (0.161)	-0.313* (0.157)	-0.377*** (0.101)	-0.426*** (0.104)	-0.370*** (0.099)	-0.413*** (0.100)	-0.414*** (0.137)	-0.321* (0.163)	-0.406*** (0.134)	-0.332** (0.162)
3	-0.338** (0.125)	-0.291** (0.133)	-0.347*** (0.124)	-0.308** (0.129)	-0.395*** (0.122)	-0.422*** (0.135)	-0.395*** (0.119)	-0.426*** (0.133)	-0.562*** (0.149)	-0.454*** (0.138)	-0.525*** (0.143)	-0.440*** (0.137)
4	-0.308** (0.145)	-0.298* (0.152)	-0.298** (0.141)	-0.299** (0.146)	-0.429*** (0.085)	-0.440*** (0.072)	-0.420*** (0.084)	-0.427*** (0.072)	-0.496*** (0.160)	-0.499*** (0.143)	-0.492*** (0.160)	-0.499*** (0.141)
5	-0.309** (0.119)	-0.316*** (0.109)	-0.317*** (0.115)	-0.320*** (0.107)	-0.303*** (0.099)	-0.299*** (0.096)	-0.306*** (0.097)	-0.298*** (0.095)	-0.673*** (0.093)	-0.615*** (0.095)	-0.657*** (0.093)	-0.609*** (0.093)
6	-0.192 (0.151)	-0.193* (0.112)	-0.204 (0.147)	-0.202* (0.109)	-0.480*** (0.079)	-0.558*** (0.070)	-0.484*** (0.079)	-0.555*** (0.068)	-0.488*** (0.132)	-0.476*** (0.120)	-0.489*** (0.134)	-0.482*** (0.122)
7	-0.267*** (0.088)	-0.313*** (0.084)	-0.271*** (0.088)	-0.318*** (0.085)	-0.383*** (0.057)	-0.401*** (0.057)	-0.380*** (0.055)	-0.403*** (0.057)	-0.635*** (0.159)	-0.661*** (0.132)	-0.601*** (0.150)	-0.637*** (0.126)
8	-0.149 (0.099)	-0.195** (0.072)	-0.156 (0.098)	-0.202*** (0.072)	-0.470*** (0.064)	-0.530*** (0.058)	-0.469*** (0.063)	-0.524*** (0.057)	-0.553*** (0.160)	-0.553*** (0.157)	-0.535*** (0.160)	-0.542*** (0.159)
9	-0.227*** (0.066)	-0.236*** (0.070)	-0.233*** (0.065)	-0.235*** (0.069)	-0.551*** (0.048)	-0.517*** (0.043)	-0.550*** (0.048)	-0.519*** (0.043)	-0.595*** (0.160)	-0.539*** (0.141)	-0.597*** (0.161)	-0.546*** (0.143)
10	-0.353*** (0.081)	-0.328*** (0.091)	-0.354*** (0.083)	-0.329*** (0.093)	-0.576*** (0.055)	-0.557*** (0.043)	-0.581*** (0.055)	-0.560*** (0.043)	-0.945*** (0.089)	-0.874*** (0.093)	-0.939*** (0.088)	-0.876*** (0.092)

Notes: Entries are price elasticities of quantity demanded (expenditure elasticity minus one). Standard errors clustered at the state level shown in parentheses below each point estimate. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Model 1: survey-weighted, no household controls. Model 2: survey-weighted, full household controls. Model 3: IPW-weighted, no household controls. Model 4: IPW-weighted, full household controls (main specification). Controls in Models 2 and 4: family size, owner-occupied, urban, number of vehicles, number of rooms. All models include state and year fixed effects. IPW = inverse probability weight correcting for non-random suppression of state FIPS codes by income decile and division. Estimation sample restricted to households with observable state FIPS codes and positive expenditure on the relevant fuel. Income decile 1 excluded. Sources: Consumer Expenditure Survey (BLS), 2005-2024; EIA State Energy Data System (SEDS).

Figure 18. Quantity Elasticities by Income Decile, Main Specification



Each line shows the point estimate of the quantity elasticity from Model 4 (IPW-weighted with full household controls) by national income decile, by fuel. Source: CEX 2005-2024; EIA SEDS.

Electricity quantity elasticities cluster between -0.20 and -0.33 across deciles, with most estimates statistically distinguishable from zero at the five percent confidence level. The pattern across deciles is essentially flat. There is no visually apparent relationship between income decile and price responsiveness for electricity.

Natural gas quantity elasticities range from -0.30 to -0.56 across deciles, all statistically significant at the one percent level. The pattern shows a tendency for elasticities to become more negative as income rises, with most decile estimates from decile 6 onward in the range of -0.40 to -0.56, compared with -0.30 to -0.43 in deciles 2 through 5. The pattern is not perfectly monotonic, but the direction is clear in the figure.

Gasoline quantity elasticities show the most pronounced income gradient. Estimates range from -0.33 at decile 2 to -0.88 at decile 10, with most intermediate deciles between -0.44 and -0.64. All estimates are statistically significant at the one percent confidence level. The decile-2 estimate is notably less negative than the rest of the distribution, and the decile-10 estimate is the most negative of any cell in the table. Higher-income households are substantially more price-responsive to gasoline than lower-income ones.

All three patterns are robust across the four model specifications. The IPW correction (Models 3 and 4) and the inclusion of household controls (Models 2 and 4) move individual point estimates by small amounts but do not alter the overall pattern across deciles for any fuel. This stability across specifications suggests that the non-random suppression of state FIPS codes does not materially affect the estimated elasticities.

The visual pattern in Figure 18 raises the question whether the apparent income gradients in natural gas and gasoline are statistically distinguishable from noise. I address this question with three tests applied to the per-decile point estimates. The precision-weighted trend test is a meta regression of elasticity estimates on income deciles weighted by inverse variance, then tests whether the slope is statistically distinguishable from zero. A negative slope means elasticity becomes more negative as income rises. Cochran's Q tests the null that all nine elasticities are equal. Unlike the trend test, it does not assume the differences are monotonic. The Spearman rank correlation is a non-parametric check for a monotonic relationship between elasticity and income decile.

Table 4 reports the results. The trend test rejects the null of no income gradient at the five percent confidence level for natural gas (slope = -0.022, $p = 0.016$) and at the one percent level for gasoline (slope = -0.051, $p = 0.002$), confirming that the apparent gradients in those fuels are not noise. Spearman rank correlations point in the same direction, with $\rho = -0.58$ for natural gas and $\rho = -0.78$ for gasoline. Cochran's Q is borderline for both fuels ($p = 0.14$ and 0.06, respectively), reflecting that the test divides its power across both linear and non-linear departures from equality. For electricity, all three tests fail to reject. The trend slope is essentially zero (slope = +0.006, $p = 0.65$) and the rank correlation is also essentially zero ($\rho = -0.02$, $p = 0.97$). The flat pattern visible in Figure 18 is supported as not just a visual impression.

Table 4. Tests of Income Gradient in Price Elasticity, by Fuel

Fuel	Trend slope	Cochran's Q	Spearman's p
Electricity	+0.006 (0.653)	2.66 (0.954)	-0.02 (0.966)
Natural Gas	-0.022** (0.016)	12.31 (0.138)	-0.58* (0.099)
Gasoline	-0.051*** (0.002)	14.95* (0.060)	-0.78** (0.013)

Notes: All three tests use the per-decile Model 4 point estimates and their standard errors as inputs. Trend slope: precision-weighted regression of the nine per-decile point estimates on decile rank, weighted by inverse variance. Cochran's Q:chi-square (8) under the null of equal elasticities. Spearman ρ: non-parametric rank correlation between elasticity and decile. P-values shown in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.10.

6.3 Interpretation

The central finding of this section is that residential energy demand is inelastic across all three fuels and all income deciles. Price increases do not trigger offsetting reductions in consumption large enough to prevent expenditure from rising. This result connects directly to the burden patterns documented in Section 5. When prices rise and consumption falls by less than the price increase, energy expenditure rises, and for lower-income households whose energy expenditure already constitutes a large share of income, the expenditure impact is substantial.

The pattern in income gradients, supported by the trend test results in Table 4, is consistent with differences in the substitution options available to households. For natural gas and gasoline, higher-income households are more price-responsive than lower-income ones. The economic interpretation is that higher-income households have more substitution options available to them. For natural gas, those options include thermostat behavior, weatherization investments, more efficient heating equipment, better-insulated homes, and the option to switch to electric heating. Lower-income households are more constrained on most of these options . They are more likely to rent rather than own and less able to invest in efficiency upgrades. For gasoline, the substitution options are similar in spirit. Higher-income households can invest in more fuel-efficient vehicles, electric vehicles, or hybrid vehicles. They have more flexibility to work from home, defer optional travel, or choose less driving-intensive housing locations. Lower-income households are more locked into existing commute patterns and vehicle types , with less ability to substitute toward fuel-efficient alternatives when prices rise.

Electricity is the exception. Quantity response is statistically significant in every decile, but there is no systematic income gradient. The plausible explanation is that the substitution options for electricity are less income-dependent. Electricity is used for many functions, including lighting, refrigeration, electronics, water heating, cooking, air conditioning, and in some divisions for space heating, that are difficult to substitute away from regardless of income. The capital and behavioral substitution options that exist for natural gas and gasoline have less analog for electricity because electricity has fewer substitutes for its core uses. Higher-income households can install solar panels or invest in more efficient appliances, but the magnitudes of those substitutions appear small enough relative to baseline consumption that they do not produce a detectable income gradient in price responsiveness.

These findings should be interpreted within their estimation constraints. The non-random suppression of state FIPS codes introduces a selection problem concentrated at the bottom of the income distribution, where suppression rates approach 16 percent in the second decile. The IPW correction applied in Models 3 and 4 and the stability of estimates across all four model specifications together suggest that this selection problem does not materially affect the elasticity estimates. The gasoline estimates face additional identification challenges from simultaneity between national gasoline prices and macroeconomic conditions, which fixed effects can absorb only imperfectly. Heating oil and propane elasticities are not estimated here because their price series have insufficient within-state variation after absorbing year fixed effects.

7. Policy Implications

The patterns presented in this paper have several implications for the design and targeting of energy assistance policy.

First, the inverse relationship between income and energy burden is steep and consistent across all divisions and all fuel types. Policies affecting energy prices, whether through carbon pricing, rate increases, or regulatory requirements, will have distributional consequences that fall disproportionately on lower-income households in dollar terms.

The elasticity estimates in Section 6 sharpen this implication. Because residential energy demand is inelastic across all three fuels analyzed, price increases translate into higher expenditure rather than being offset by proportional reductions in consumption.

Second, the income gradient in elasticity for natural gas and gasoline means that lower-income households face a compounding disadvantage when prices rise for those fuels. They start with higher baseline burden, as the descriptive analysis shows, and they reduce consumption less than higher-income households when prices rise. For both fuels, a given price increase raises expenditure burden more for a household in the second income decile than for one in the tenth. The substitution options framing suggests that this gap reflects differences in the capital and behavioral options available to households at different income levels. For electricity, the absence of an income gradient means that price changes affect expenditure burden roughly proportionally across the income distribution.

Third, the geographic heterogeneity in burden suggests that geographically uniform assistance formulas may not match the distribution of need. A program that allocates LIHEAP funds proportional to population, for example, will allocate fewer dollars per high-burden household in the East and West South Central divisions than in the Pacific and Middle Atlantic divisions. Burden-adjusted formulas would direct more resources toward divisions with higher burden levels.

Fourth, the fuel-type composition of burden differs substantially by division. Natural gas burden is highest in the North Central divisions where heating loads are largest and natural gas use is most prevalent. Heating oil burden is concentrated in New England and the Middle Atlantic. Gasoline burden is highest in the East and West South Central divisions, where driving distances are long and incomes are lower than the national average. Electricity burden is heaviest in the East and West South Central divisions, reflecting cooling demand. Programs designed around a single fuel type such as weatherization programs that focus on heating efficiency will reach different populations depending on where they are deployed.

Fifth, the long-run decline in natural gas prices between 2008 and 2020 provided a substantial real income benefit to households across all divisions with the largest absolute benefit accruing to households in cold-climate divisions where natural gas heating predominates. The partial reversal of that decline after 2020, visible in Figure 3, has implications particularly for low-income households in natural gas-dependent divisions, who face the burden consequences most directly because of their lower price responsiveness.

Sixth, the inelasticity of residential energy demand has direct implications for the design of price-based policy instruments. A carbon price or rate increase intended to reduce consumption will achieve less reduction than an elastic demand assumption would predict, and will impose larger expenditure burdens on low-income households than on high-income ones. The natural gas and gasoline elasticity gradients, where lower-income households are less price-responsive, make price-based instruments particularly blunt for achieving conservation goals at the bottom of the income distribution. Efficiency investments, weatherization programs, vehicle replacement programs, and targeted assistance are better matched to the substitution patterns the data reveal. Where the substitution options are capital investment that lower-income households cannot finance on their own, programs that subsidize or finance those investments directly may achieve more conservation per dollar than price-based instruments alone.

8. Conclusion

Energy affordability is not the same problem everywhere. A household struggling to pay its utility bills in rural Mississippi faces a different situation than one in suburban Boston, even at the same income level. Different fuels, different prices, and different consumption patterns result in a different share of income going out the door to keep the lights on and the house warm.

This paper has documented those differences. Using twenty years of Consumer Expenditure Survey data merged with state-level energy price data, I show that the East and West South Central divisions have the highest burden for low-income households, and that Pacific and Middle Atlantic, despite paying high prices for electricity, have among the lowest burden because their higher incomes more than offset the higher prices they pay. I show that the shale revolution’s impact on natural gas prices produced a substantial real reduction in energy costs for most households, and that electricity prices are now rising in the Pacific division toward levels previously seen only in New England.

I also show that residential energy demand is inelastic across the three fuels for which reliable estimation is possible (electricity, natural gas, and gasoline) and across all income deciles. The income gradient in elasticity differs across fuels in a way consistent with differences in substitution options. For natural gas and gasoline, higher-income households are more price-responsive than lower-income ones, plausibly because they have more capital-investment and behavioral substitution options available to them. For electricity, price responsiveness does not vary systematically by income, plausibly because electricity has fewer income-dependent substitution options. Heating oil and propane elasticities are not estimated because their state-level price series do not contain enough within-state variation after absorbing year fixed effects.

These patterns do not resolve debates about energy policy, but they provide the factual basis those debates require. Understanding who bears the burden of residential energy costs, where that burden is highest, which fuels drive it, and how households respond when prices change are necessary inputs to designing policies that address that burden effectively.

References

Alberini, Anna, Will Gans, and Daniel Velez-Lopez. 2011. "Residential Consumption of Gas and Electricity in the U.S.: The Role of Prices and Income." Energy Economics 33(5): 870-881.

Batlle, Carlos, Peter Heller, Christopher Knittel, and Tim Schittekatte. 2024. "U.S. Federal Resource Allocations Are Inconsistent with Concentrations of Energy Poverty." Science Advances 10(41): eadp8183.

Bednar, Dominic J., and Tony G. Reames. 2020. "Recognition of and Response to Energy Poverty in the United States." Nature Energy 5(6): 432-439.

Borenstein, Severin. 2012. "The Redistributional Impact of Nonlinear Electricity Pricing." American Economic Journal: Economic Policy 4(3): 56-90.

Borenstein, Severin, and Lucas W. Davis. 2012. "The Equity and Efficiency of Two-Part Tariffs in U.S. Natural Gas Markets." Journal of Law and Economics 55(1): 75-128.

Bureau of Labor Statistics. Consumer Expenditure Survey public-use microdata, 2005-2024. U.S. Department of Labor. https://www.bls.gov/cex/pumd_data.htm

Bureau of Labor Statistics. CPI-U All Items, Series CUUR0000SA0. U.S. Department of Labor. https://data.bls.gov/timeseries/CUUR0000SA0

Drehobl, Ariel, Lauren Ross, and Roxana Ayala. 2020. How High Are Household Energy Burdens? An Assessment of National and Metropolitan Energy Burden Across the United States. ACEEE Report U2006. Washington, DC: American Council for an Energy-Efficient Economy.

Energy Information Administration. State Energy Data System (SEDS): Prices and expenditures. U.S. Department of Energy. https://www.eia.gov/state/seds/

Espey, James A., and Molly Espey. 2004. "Turning on the Lights: A Meta-Analysis of Residential Electricity Demand Elasticities." Journal of Agricultural and Applied Economics 36(1): 65-81.

References (continued)

Miller, Mark, and Anna Alberini. 2016. "Sensitivity of Price Elasticity of Demand to Aggregation, Unobserved Heterogeneity, Price Trends, and Price Endogeneity: Evidence from U.S. Data." Energy Policy 97: 235-249.

Schulte, Isabella, and Peter Heindl. 2017. "Price and Income Elasticities of Residential Energy Demand in Germany." Energy Policy 102: 512-528.

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