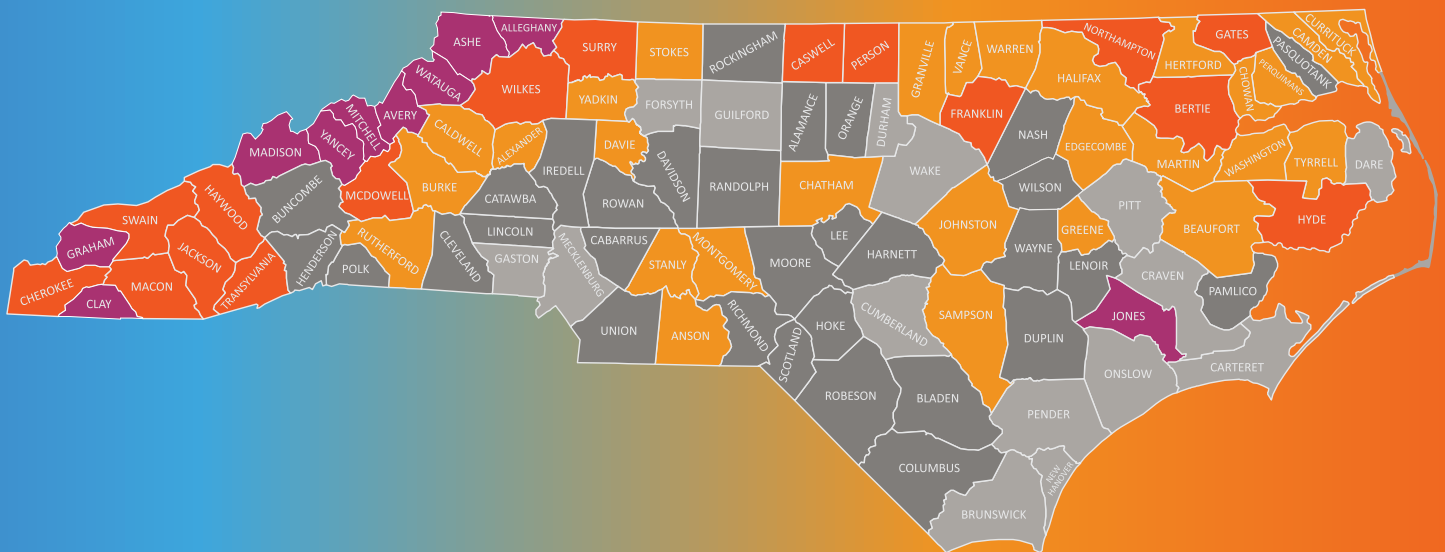


# A CALL TO ACTION: ANALYZING RURAL ENERGY BURDENS IN NORTH CAROLINA

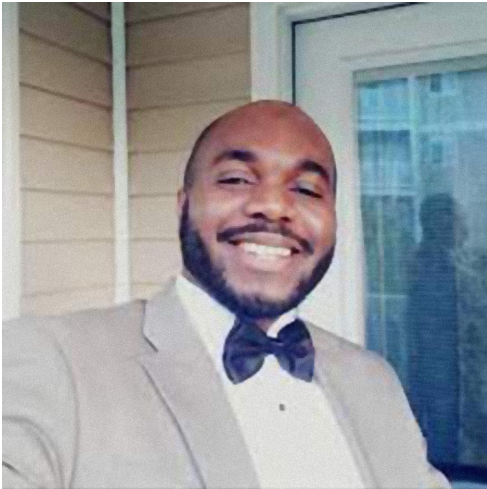


## REPORT



[www.groundswell.org](http://www.groundswell.org)

# A CALL TO ACTION: ANALYZING RURAL ENERGY BURDENS IN NORTH CAROLINA




## ABOUT THE AUTHOR

Groundswell's data science and research efforts are led by Dr. Elvis Moleka, who joined Groundswell in 2020. He conducts research and analysis on the vertices between sustainable finance, development economics, energy economy, risk management, financial markets, monetary policy, and macroeconomic dynamics. Before joining Groundswell, he worked as a Senior Financial Consultant and supported Model Risk Management groups on model validation for major Wall Street Banks. He held Lectureship positions at the University of Warwick, University of Bath, London Metropolitan University, and the University of Buea. Dr. Moleka earned his Doctor of Philosophy in Economics from the University of Bath. He earned a Master of Science in Business Economics and Finance from London Metropolitan University and a Bachelor of Science in Economics from the University of Buea. He is also the Co-Founder and CEO of Leka Research Institute LLC and Chairs the Economic and Development Committee at BACDU USA Inc. For further information, please email: [research@groundswell.org](mailto:research@groundswell.org).

## ACKNOWLEDGMENTS

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 With gratitude to Google, who inspired and supported this research with their values-driven desire to advance energy equity in the communities where they operate.

# ABSTRACT

*This paper examines household energy burdens in North Carolina at a county level, using community and energy data from the years of 2015 and 2020. This research underscores how local and state governments can collaborate to implement meaningful energy efficiency programs and clean energy projects in rural communities. The research indicates that energy efficiency would decrease poverty and increase financial security and housing equity in North Carolina. This paper identifies recommendations and tools for utilities to better support low and moderate-income (LMI) households in North Carolina.*

**KEYWORDS:** energy burden, low-income, energy efficiency, North Carolina

**JEL CLASSIFICATION:** C10, C38, C55, Q40, Q47 and Q48

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# EXECUTIVE SUMMARY

## *Research Highlights:*

- While North Carolina has lower electricity rates (11.24 ¢ / kWh) than the national average (of 14.12 ¢ / kWh), North Carolina's statewide average energy burden for low and moderate-income (LMI) households is 19.8% — significantly above the 6% threshold that is widely agreed upon as delineating high energy burdens.
- The average energy burden for North Carolina households living at 50% of the Federal Poverty Level (FPL) is 32.8%, meaning these households have energy burdens five times higher than North Carolina households earning \$55,500 (or 200% FPL) or more per year. These comparatively higher-earning households have an average estimated energy burden of 6.8%, which is still considered a high energy burden.
- Rural counties across North Carolina carry the heaviest energy burdens across all income brackets. These high energy burdens result partially from energy inefficient housing and an increasing number of cooling degree days and heating degree days in the region stemming from climate change.
- Avery County residents have the highest energy burdens out of all the counties in North Carolina. With a population of approximately 17,506, Avery County households who live below 50% of the FPL face electricity bills that cost an average of 43.2% of their total household income. Meanwhile, Avery County households earning up to 100% of FPL spend more than 23% of their household income on electricity bills.
- North Carolina households living at 50% of the FPL face energy burdens ranging between 27.71% and 43.2%, regardless of county. These high energy burdens result partially from energy inefficient housing and an increasing number of cooling degree days and heating degree days in the region stemming from rising climate conditions.
- While federally funded, statewide aid programs like LIHEAP can help pay high bills for income-qualified residents, they do not address root causes and are insufficient. In 2020, LIHEAP only served 22% of income-qualified North Carolina residents. (<https://liheappm.acf.hhs.gov/sites/default/files/private/congress/profiles/2020/FY2020NorthCarolinaProfile-508Compliant.pdf>)
- Many rural counties with high energy burdens also have no solar farms, although solar farms are common throughout North Carolina, which is a Top 10 solar state<sup>1</sup>, according to the Solar Energy Industries Association. (Appendix B)

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<sup>1</sup> <https://www.seia.org/research-resources/top-10-solar-states-0>

## ***A Call to Action:***

- Most rural counties in North Carolina are served by locally-owned and governed rural electric cooperative and municipal utilities – not investor-owned utilities which are regulated by the North Carolina Utilities Commission (NCUC).
- To address rural residents' high energy burdens and poverty, North Carolina needs energy efficiency programs designed to serve low and moderate-income households receiving electricity through rural electric cooperatives and municipal utilities. For optimal results, these programs should make use of existing rural electric cooperatives and municipal utility providers and/or serve residents directly through legislatively directed statewide programs.
- Implementing these programs will require leadership from the Governor and Lieutenant Governor, the North Carolina State Legislature, local municipalities, and/or rural cooperative utilities. No one agency can do it alone because of the diversity of regulatory oversight and governance across different types of utilities.
- US Department of Agriculture (USDA) initiatives — including the Rural Energy Savings Program — can be used to further support and enhance state level efforts.
- Rural North Carolina utility Roanoke Electric Cooperative is a national leader in energy efficiency, solar, energy storage, and electric vehicle programs that reduce energy burdens, benefit low-income residents. Their programs may be replicable in other communities to benefit rural, energy burdened North Carolinians statewide.<sup>2</sup>

## ***Key Terms:***

- Energy Burden: The percentage of total household income spent on energy bills. This specifically refers to the total household energy utility expenditure for heating and cooling and excludes water and transportation expenditures.
- Federal Poverty level (FPL): The United States Department of Health and Human Services defined FPL as a household income of \$27,750 per year as of 2022. (<https://aspe.hhs.gov/topics/poverty-economic-mobility/poverty-guidelines>).
- Cooling Degree Days and Heating Degree Days: Days where the outdoor temperatures require indoor cooling and heating usage, respectively.

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<sup>2</sup> [https://www.southernenvironment.org/wp-content/uploads/legacy/infographics/SELC\\_Roanoke\\_Electric\\_OBF\\_Handout\\_Final.pdf](https://www.southernenvironment.org/wp-content/uploads/legacy/infographics/SELC_Roanoke_Electric_OBF_Handout_Final.pdf)

# 1 EXAMINING COUNTY-LEVEL ENERGY BURDENS IN NORTH CAROLINA

In September 2021, Groundswell published “Energy Impoverishment and Energy Insecurity in the United States.” Researched and written by Dr. Elvis Moleka, this milestone study found that energy burdens for low and moderate-income (LMI) households were higher in rural communities, and seven states stood out due to exceptionally high energy burdens impacting LMI households, with LMI households in those states facing energy bills averaging more than 20 percent of total household income. For example, the average LMI household in Vermont pays 27.2% of its entire household income for electricity, as shown in Table 1 below. These findings revealed a clear need for action to address high energy burdens and energy poverty. However, a review of these findings highlighted that energy burdens in each state are influenced by unique factors, especially for LMI households, and actions meant to address high energy burdens and energy poverty would need to vary accordingly. With this knowledge in mind, Groundswell launched an ambitious initiative to research and produce reports for all fifty states and Washington, DC. The first report was published for Georgia in March 2022. This report on North Carolina is the second in the series.

Table 1

## Worst LMI Energy Burdened States

State	LMI Energy Burden (%)
Alaska	42.4%
Maine	40.4%
Vermont	27.2%
Mississippi	26.7%
Hawaii	23.1%
South Carolina	22.0%
Alabama	20.9%
North Carolina	19.8%

Note. Retrieved from (Moleka, 2021).

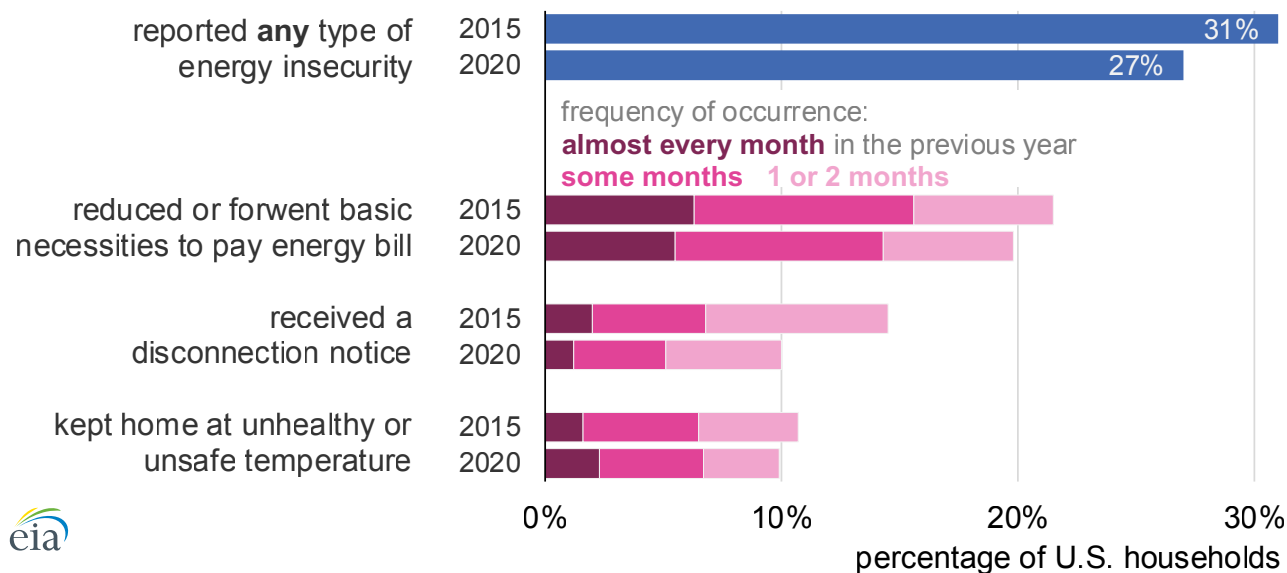
As shown in **Table 1**, North Carolina experiences the eighth highest energy burden in the United States, on average. **In each of these states — and across the country as a whole — data analysis proves that energy burdens are heavier in rural communities, compared to urban communities in the same region.** According to 2019 US Census data<sup>3</sup>, “more than 400,000 households in North and South Carolina live at 50% of the federal poverty line, and face average energy burdens of 30% (NC) and 37% (SC).” A recent study by the US Energy Information Administration (EIA), suggests that in 2020, 27% of American households had trouble affording to pay their energy bills due to unsustainable energy costs. While this estimate is a minor improvement compared to the 31% of Americans who reported that same challenge

3 [https://convergence.unc.edu/vulnerabilities/energy-poverty/#:~:text=According%20to%20the%20latest%20U.S.,and%2037%25%20\(SC\).](https://convergence.unc.edu/vulnerabilities/energy-poverty/#:~:text=According%20to%20the%20latest%20U.S.,and%2037%25%20(SC).)

in 2015 — as shown in **Figure 1** (below) — high energy burdens impact American lives in significant ways. In 2020, an average of 19% of all Americans forwent basic needs to keep their lights on.<sup>4</sup> Energy insecurity and energy costs remain high across the country, especially in more burdened states like North Carolina.

**Figure 1**

### US Household Energy Insecurity Measures (2015 and 2020)



## Who delivers electricity, and energy efficiency, to energy-burdened rural North Carolina?

North Carolina has thirty-one rural electric cooperatives (twenty-six are headquartered in NC and about seventy-five electric utilities owned by municipalities or universities.) Together, these 106 entities serve half the state’s residents and most of its landmass, as shown in the map on the next page (**Figure 2**). Rural electric cooperatives are nonprofit utilities that are owned and governed by their member-customers through democratically elected boards. Municipal utilities are part of the local government and are typically governed by local city councils.

State regulated, investor-owned electric utilities (IOUs) are the dominant electricity providers for urban and industrial areas in North Carolina. Duke Energy Carolinas, Duke Energy Progress, and Dominion Energy North Carolina are IOUs that serve most utility customers in North Carolina. These utilities are regulated by the NCUC, whose members are appointed by the Governor subject to confirmation by the General Assembly.

Rural electric cooperatives, in contrast, serve most of North Carolina’s energy burdened rural counties. In North Carolina, rurality is defined as any county with a total population of 50,000 people or less. Stemming from the history of rural electrification in America, when rural electric cooperatives were created to turn

<sup>4</sup> <https://www.eia.gov/todayinenergy/detail.php?id=51979>



the lights on for farming communities that for-profit utilities refused to serve because it was unprofitable, these small nonprofit utilities still serve less densely populated areas with high poverty rates. Nationally, rural electric cooperative utilities serve more than 90 percent<sup>5</sup> of the persistent poverty counties in the US.

## ROANOKE ELECTRIC COOPERATIVE – Leadership Reducing Energy Burdens

Roanoke Electric Cooperative is a rural cooperative utility located in Northeastern North Carolina. Roanoke Electric Cooperative became a national leader in innovative energy programs under the visionary leadership of prior CEO Curtis Wynn – a tradition that current CEO Marshall Cherry is advancing. From Upgrade to Save, a pioneering Pay As You Save (PAYS) on-bill program that pays for energy efficiency upgrades with energy savings, to community solar programs that share savings with member-customers, to innovative electric vehicle rates and vehicle-to-grid charging that helps customers save money and reduce transportation costs – Roanoke Electric Cooperative is setting examples that rural utilities across North Carolina and the nation can follow. If you want to see what the utility of the future looks like, visit Roanoke Electric Cooperative.

*For more information about energy efficiency programs available in North Carolina, consult the ACEEE state and local policy database, available at <https://database.aceee.org/state/north-carolina>.*

The structural differences between IOUs, which are regulated by the NCUC, and rural electric cooperatives and municipal utilities, which are governed locally, and which have nonprofit business models, mean that local action, potentially supported with state legislative policies, would be required to implement initiatives to reduce energy burdens for rural communities statewide. **Table 2** (next page) summarizes the percentage of residential customers by utility type in North Carolina.

As we will see in detail, low and moderate-income North Carolina households carry high energy burdens – particularly in rural counties. However, these energy burdens do not directly correlate with utility rates in North Carolina as the state’s utility rates fall below the national average. This combination of high energy burdens and low energy rates indicates that high energy burdens in the state are driven by high energy usage related to a lack of energy efficiency.

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<sup>5</sup> <https://www.electric.coop/issues-and-policy/environment>



Table 2

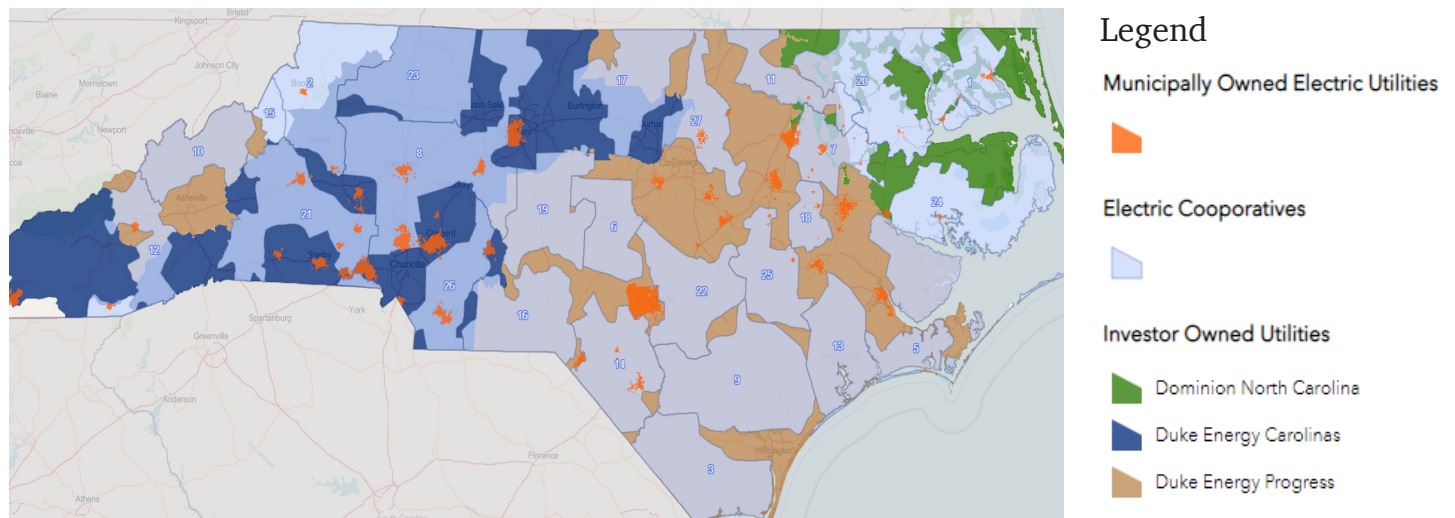
## Proportion of Residential Customers in North Carolina by Utility Type

Utility Type	# of Residential Customers	% of Total Customers
<b>Investor-Owned Utilities (IOUs)</b>		
Duke Energy Carolina	2,005,000	39.10%
Duke Energy Progress	1,402,000	27.34%
Dominion Energy North Carolina	121,000	2.36%
<b>Cooperative Utilities</b>	1,000,000	19.50%
<b>Municipal and University-owned Utilities</b>	599,000	11.68%
<b>Total</b>	<b>5,127,000</b>	<b>100%</b>

Note. Retrieved from NCUC (2020)<sup>6</sup>

Figure 2

## Utility Service Territories in North Carolina



Source: North Carolina Sustainable Energy Association<sup>7</sup>

<sup>6</sup> <https://www.ncuc.net/documents/overview.pdf>

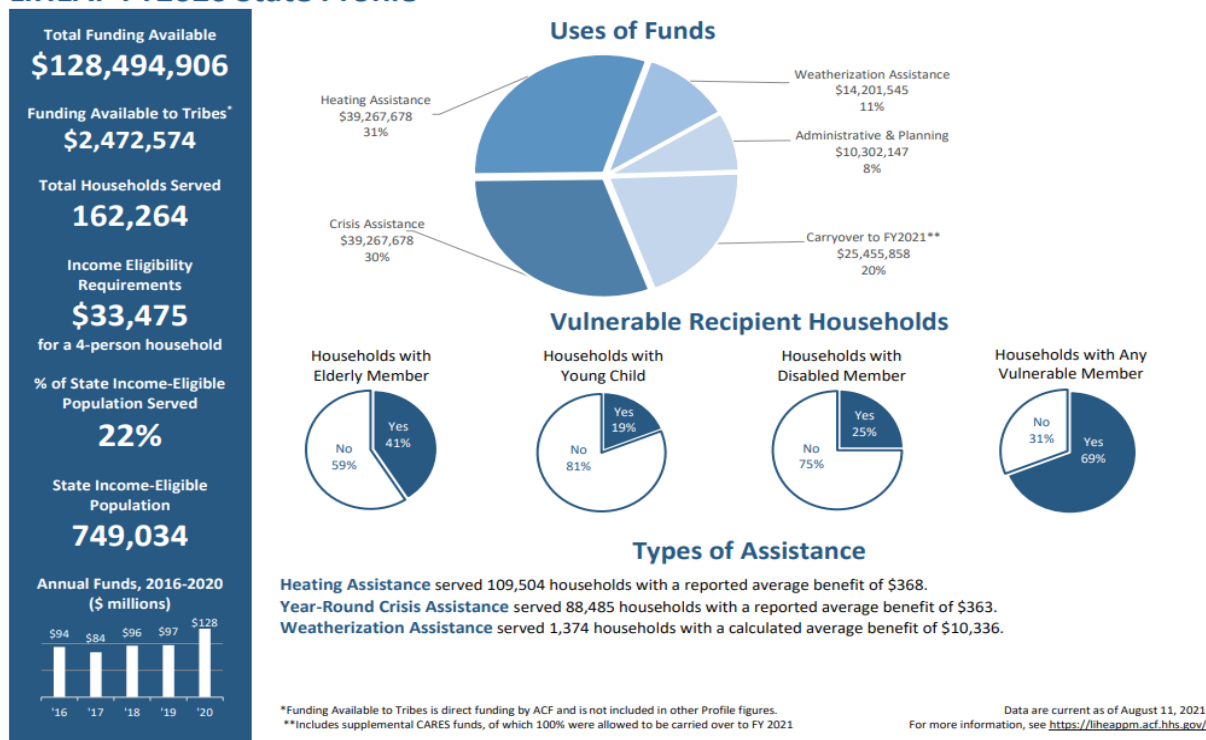
<sup>7</sup> <https://ncseamaps.maps.arcgis.com/apps/webappviewer/index.html?id=d142d97344df494aa20a519c74876e53>

Figure 3

## North Carolina LIHEAP 2020 State Profile

### North Carolina

#### LIHEAP FY2020 State Profile



*The Low Income Home Energy Assistance Program (LIHEAP) is a federally funded program that pays for utility bill assistance and home weatherization for income-qualified households.*

## 2 DEVELOPMENTAL EVIDENCE

This report makes the following contributions to the literature.

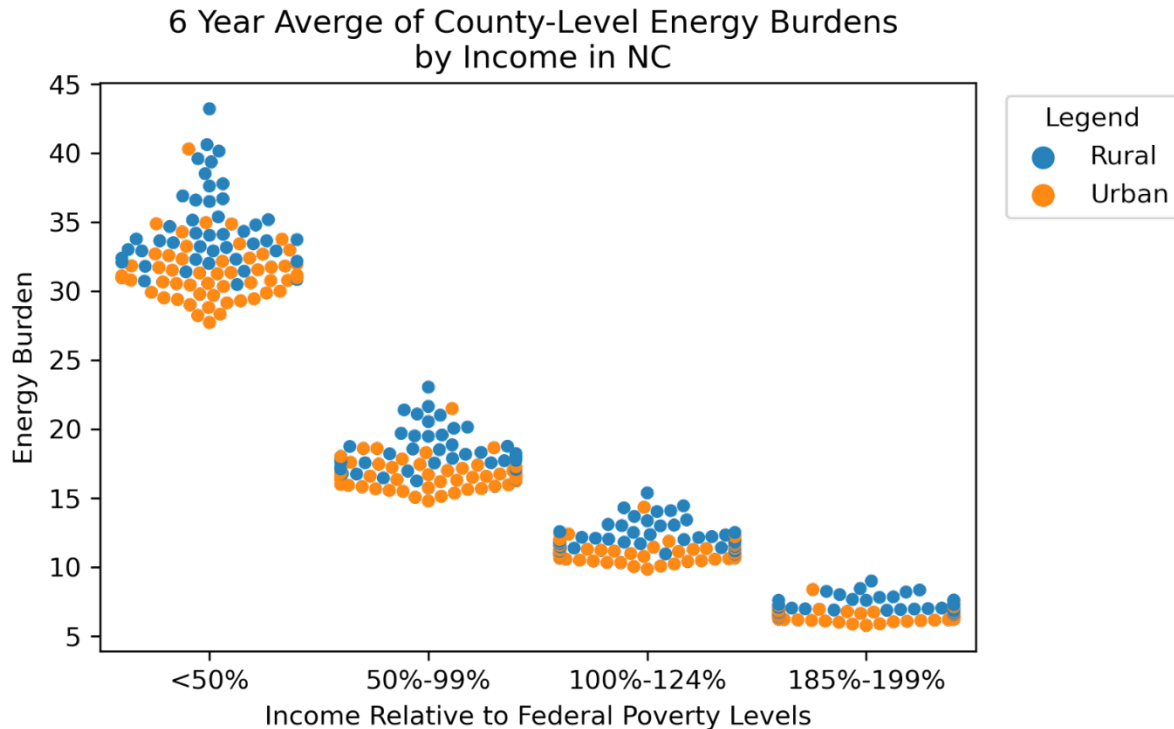
- This research identifies the most energy burdened counties in North Carolina by income level to aid prioritization of policy measures aimed at supporting LMI households in North Carolina.
- This research examines the differences in energy burdens in households in North Carolina, focusing on families in rural communities and families with LMI.
- This research also explores factors contributing to differences in energy burdens throughout the state.

The authors have grouped energy burdens based upon two characteristics:

- A classification approach was used to determine whether a county is rural or urban based on county population. North Carolina defines a county with a population of less than 50,000 people as rural.
- In this report, households are categorized by four income brackets: 50% Federal Poverty Levels (FPL) or less, between 50% and 99% FPL, between 100% and 124% FPL, and between 185% and 199% of FPL<sup>8</sup> respectively. A swarm plot was used to depict the 6-year average energy burden for each of the four income brackets in every North Carolina County while indicating whether a county is rural or urban.<sup>9</sup> As shown in **Figure 4** (below), each point is grouped by income bracket along the x-axis and color-coded by its location type – whether rural or urban. Energy burden is considered as the dependent variable and plotted along the y-axis.

Figure 4

### 6 Year Average of County-Level Energy Burdens by Income in North Carolina



<sup>8</sup> The Federal Poverty Level as defined in 2021 by the US Department of Health and Human Services is used throughout this report. FPL is used to determine financial eligibility for many state-funded programs.

<sup>9</sup> North Carolina defines rurality as counties with population less than 50,000.

**Figure 4** clearly shows the inverse relationship between income and energy burden, meaning as income rises, energy burden decreases. Most distinctively (as seen in Appendix C), compared to Georgia and South Carolina, North Carolina shows the largest and most clear-cut differences between rural and urban household energy burdens within the same income brackets. In Figure 4, there is significantly less mixing of the blue and orange data points in each grouping than in Georgia or South Carolina. Blue points are noticeably at the top of every grouping, and orange points are the bottom. This positioning suggests that rural energy inequity plays a much larger and more distinct role in energy burdens in North Carolina than in Georgia and South Carolina. In each income bracket grouping for North Carolina, we see that the highest energy burdens are all from rural counties, and the spread is much larger (see Table 4 in this report) for North Carolina households at 50% or less of the FPL. In contrast, the 185%-199% FPL group has the narrowest<sup>10</sup> energy burden distribution.

## ***2.1 Fuel Type as an associated cause of Energy Burden in North Carolina***

While electricity availability and rates are not much different for rural households compared to urban and suburban households, problems with access to natural gas and high heating costs are much more common. North Carolina generally has a warmer climate – implying North Carolina has more cooling degree days than other states. The far western region of the state, however, experiences temperatures of about 10 degrees Fahrenheit lower than the far eastern region of the state.

Natural gas remains the standard heating fuel option in many areas, especially in more northern climates in the US, although heat pumps offer similar costs to operate, are cleaner, are safer, and run-off of electricity. In rural North Carolina, as in many rural communities, natural gas is not available, so many households use fossil-fuel based heating systems that run on fuel oil or bottled gas such as propane. These styles of fossil fueled heating systems are much more expensive to use, as depicted in Figure 5, and will only rise in operating costs as the cost of fuel increases.

**Figure 5** below shows the average energy burden by fuel type, while **Figure 6** depicts the change of propane prices over time in North Carolina. Of the households (HH) in the 0%-100% FPL bracket in North Carolina, a majority uses electricity as their main heating source (368,858 HH), about 78,648 HH use natural gas, 31,616 use bottled gas, and 22,130 use fuel oil. The energy burdens of the households within the 0%-100% FPL bracket using electricity and natural gas were 16% and 18%, respectively. However, the mean energy burden for houses using fuel oil was 20%, and the mean for the households using bottled gas was 34%. It is believed that many of the households using fuel oil or bottled gas likely had their furnaces installed when these types of fuel sources were much more affordable than in today's competitive rates. Over time, fossil fuel prices rose significantly. The most common type of bottled gas used in North Carolina is propane.

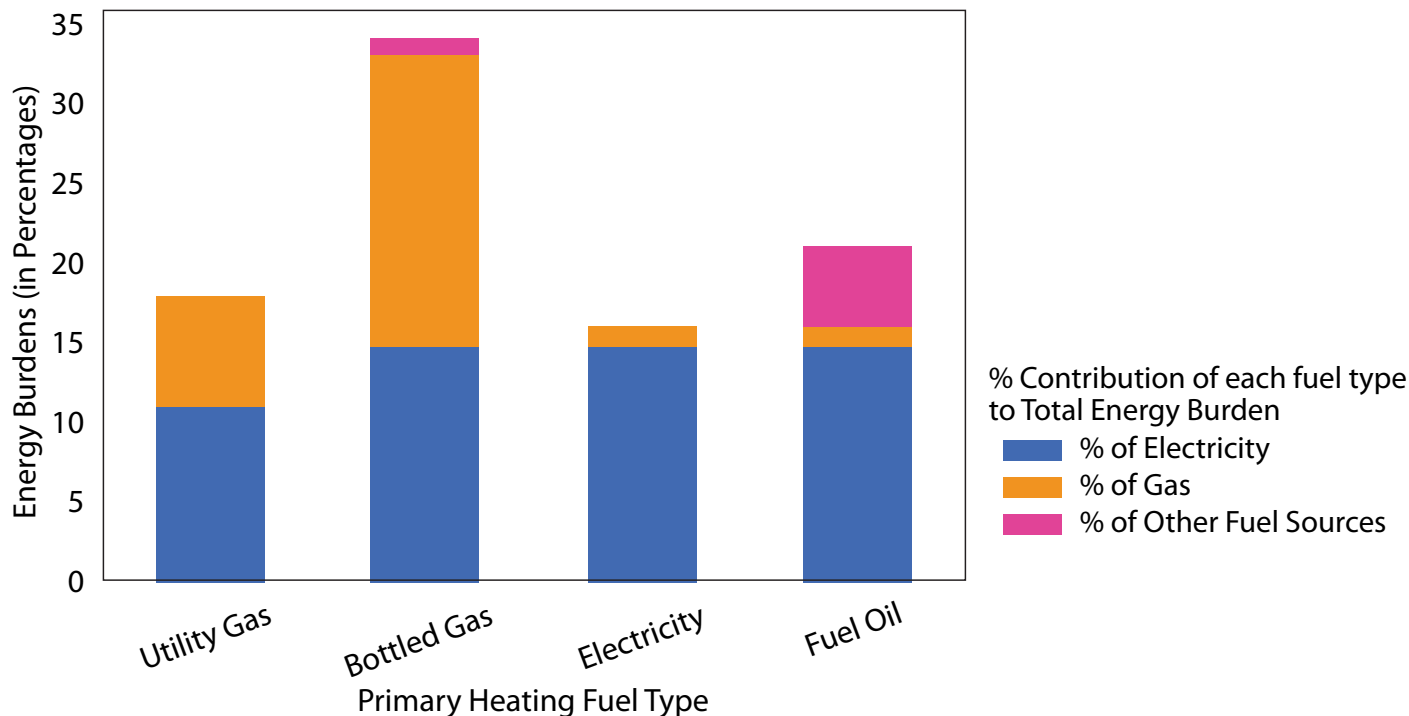
When examining major household expenses and their impact on the financial wellbeing of families and individuals, energy bills are often left out. While expenses like rent/mortgage payments, groceries, vehicle payments, and gasoline costs may be high, they are easier to budget for in that they are predictable and constant. However, residential energy expenses can vary greatly depending on the weather during a specific month or year. No other regular expense paid by such a large segment of the US population varies as much from month to month as energy costs.

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<sup>10</sup> As explained by the standard deviation.

Figure 5

## Average Energy Burdens for Home with <100% FPL by Primary Heating Type in North Carolina



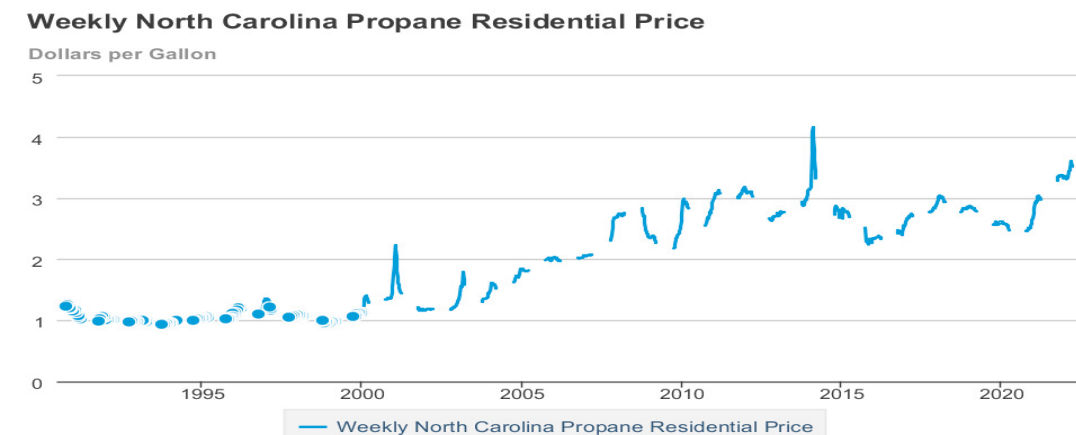
As evidenced in **Figure 6** (next page), the price of propane in North Carolina is plotted between 1990 and 2022.

In the early 2000s, the price of propane was around \$1.00 USD/gallon. At the time of writing, the average price for propane was \$3.521 USD/gallon according to the most recently published weekly average price for propane for residential use, released March 28, 2022. Hence, in 2022, bottled fuel users pay over three times more for heating than they paid in 2000, which is far above the average US inflation of 70% since 2000<sup>11</sup>. The second notable trend in these data is that the price of propane is highly unstable. **This instability makes it more difficult for households with limited income to budget properly for heating costs due to uncertainties regarding future propane price increases.**

<sup>11</sup> [https://www.bls.gov/data/inflation\\_calculator.htm](https://www.bls.gov/data/inflation_calculator.htm)

Figure 6

## Weekly Propane North Carolina Residential Price



eia Source: U.S. Energy Information Administration

## 2.2 Summary Statistics of Energy Burden Rankings in North Carolina

Table 3 below shows the distribution of energy burdens by income in North Carolina, while Table 4 is a summary of North Carolina's most energy impoverished. A complete list of county-by-county energy burden rankings in North Carolina is available in Appendix A.

Table 3

### Summary Statistics of Energy Burden in North Carolina by Federal Poverty Levels

Federal Poverty Income Level (FPL)	count	mean	std	min	25%	50%	75%	max
185%-199%	100	6.8	0.6	5.8	6.4	6.7	7.1	9
100%-124%	100	11.7	1.1	9.8	11	11.5	12.1	15.4
50%-99%	100	17.5	1.6	14.8	16.4	17.2	18.2	23
<50%	100	32.8	3	27.7	30.8	32.2	34	43.2

These statistics show that the lower the household income, the higher the household energy burden. The median energy burden for households at less than 50% of the FPL is above 30% of total income, compared to 7% or less for North Carolina households between 185% and 199% of the FPL.

Table 4

### Most Energy Burdened Counties in North Carolina by Federal Poverty Levels (In 2022, FPL for a family of four is \$27,750)

Rank	Counties	Rural or Urban	<50%	50%-99%	100%-124%	185%-199%
1	Avery County	Rural	43.2	23	15.4	9
2	Ashe County	Rural	40.6	21.6	14.4	8.4
3	Watauga County	Urban	40.3	21.5	14.3	8.4
4	Madison County	Rural	40.1	21.4	14.3	8.3
5	Mitchell County	Rural	39.6	21.1	14.1	8.2
6	Yancey County	Rural	39.4	21	14	8.2
7	Jones County	Rural	38.5	20.5	13.7	8
8	Clay County	Rural	37.8	20.1	13.4	7.8
9	Alleghany County	Rural	37.6	20.1	13.3	7.8
10	Graham County	Rural	36.9	19.7	13.1	7.7

## 2.3 Benchmarking Analysis of Energy Poverty in North Carolina

This section provides a comparative analysis of the energy burden numbers derived from the comparative analysis for the most energy burdened counties in North Carolina with the energy burden numbers published by the Convergence of Climate Health for North Carolina.

Table 5

### Benchmark Analysis – Comparison of Energy Burdens at less than 50% FPL in North Carolina

Rank	Counties	Rural or Urban	Household Median Income (<50% FPL)	<50% Moleka (2022)	<50% Convergence of Climate Health (2019)	<50% Difference
1	Avery County	Rural	\$20,400	43.2	43.3	0.1
2	Ashe County	Rural	\$24,100	40.6	40.6	0
3	Watauga County	Urban	\$19,700	40.3	40.5	0.2
4	Madison County	Rural	\$25,100	40.1	40.2	0.1
5	Mitchell County	Rural	\$25,100	39.6	39.5	0.1
6	Yancey County	Rural	\$14,500	39.4	39.0	0.1
7	Jones County	Rural	\$22,200	38.5	37.5	1
8	Clay County	Rural	\$26,300	37.8	37.5	0.3
9	Alleghany County	Rural	\$20,800	37.6	37.4	0.2
10	Graham County	Rural	\$20,300	36.9	36.1	0.8

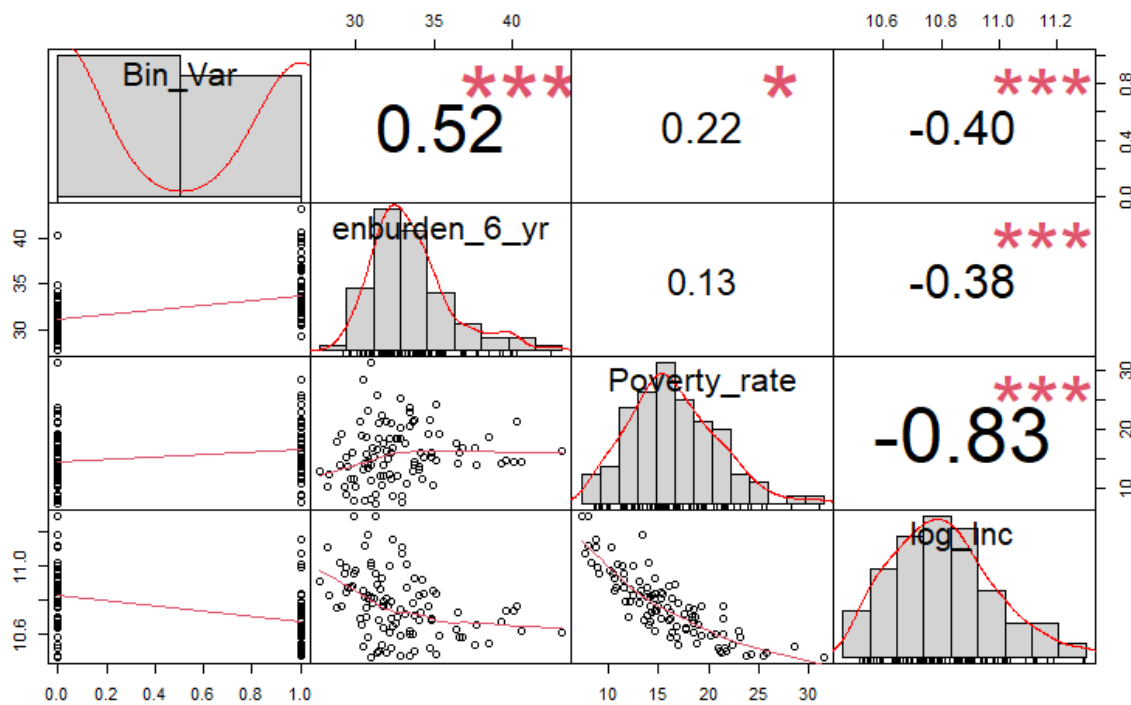
Note: For a family of four, FPL is \$27,750



The above analysis indicates that energy burden distributions in rural counties are much wider and skew to higher energy burdens. The data in the upcoming empirical sections are based on 50% or less of the FPL because this category represents the utility customers who are most affected by high energy burdens and income inequities. This impact is especially evident in households in the rural areas compared to more affluent, urban counties. **Figure 7** (below) shows the correlation plot, with histograms, density functions, smoothed lines, and correlation coefficients for the predictor variable against energy burden, county-level poverty rate and the natural logarithm of median household income. These visualizations provide evidence of significant correlations between the dependent variable and the explanatory variables within this analysis. Rurality (the dependent – binary variable) is positively correlated with energy burden and poverty rate. However, as expected, rurality was negatively correlated with county-level median household income. **This analysis confirms our hypothesis that counties with the lowest median household income are most likely to be energy impoverished.**

Figure 7

### Spearman Correlation Analysis of Energy Burden Rurality in North Carolina



### 3 DATA AND RESULTS

County-level home energy burden data between 2015 and 2020 was obtained from the Home Energy Affordability Gap<sup>12</sup> (Fisher et al., 2020) analysis. This data was considered together with demographic and housing data from the US Census Bureau<sup>13</sup> — and the American Community Survey for North Carolina. The values used to calculate energy burden as used in this report are the total amount spent on energy bills, including heating, cooling, and electricity.<sup>14</sup> This measure of energy burden is defined simply as the percentage of total household income that must be allocated to household energy costs.

In North Carolina, LMI households have been shown to have energy burdens exceeding 19% of their total household income. Comparatively, non-LMI households were shown to have energy burdens of less than 8% (Moleka, 2021). With a population of approximately 10.49 million, and a total surface area of 53,819 square miles, there are an average of 196 people for every square mile — making North Carolina the 15<sup>th</sup> most densely populated state in the US. This average statewide population density made the difference between rural and urban energy burdens especially striking.

In the “Baseline Model,” the dependent variable, a measure of rurality, is regressed against county-level energy burden, poverty rate, and the natural logarithm of median household income at the county-level on a constant term. The “Demographic Model,” as used in this paper, extends the baseline model while controlling for the proportions of the African American, Asian, and Hispanic populations — as studies have shown that these groups are more susceptible to high energy burdens, compared to other demographic populations (Moleka, 2021; Drehoobl and Ross, 2016). The “Population Model” controls for the variance in the entire population as an instrument. The coefficient of energy burden, poverty rate, and the natural logarithm of median household income are significant at the 5% statistical level. The results of this analysis show that energy burden’s impact on racial inequality and poverty are severe in North Carolina when controlling for population demographics.

The coefficient of energy burden, poverty rate and the natural logarithm of median household are significant at the 5% level. In North Carolina, poverty rate is negative, suggesting that North Carolina has more affluent rural counties with better living standards compared to Georgia (Moleka, 2021). This analysis also shows that rurality tends to be negatively correlated with median household income in North Carolina as expected.

Diagnostic tests were performed to validate the coefficient estimates of the results as shown in the **Table 7** (next page). Higher order autocorrelations were conducted using the Breusch-Godfrey test, while tests for heteroskedasticity were performed using the Breusch-Pagan and Goldfeld-Quandt tests. The validity of the functional specification is shown by the Rainbow and Harvey-Collier tests. In all cases, the null hypothesis of no misspecification in the functional form cannot be rejected.

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12 What is the home energy affordability gap? Accessed at: [http://www.homeenergyaffordabilitygap.com/01\\_whatIsHEAG2.html](http://www.homeenergyaffordabilitygap.com/01_whatIsHEAG2.html)

13 Accessed at: <https://www.census.gov/quickfacts/fact/table>

14 It is important to note that natural gas and fuel prices are other determinants of energy costs.

Table 6

**Energy Inequity and Rurality Analysis in North Carolina: <50% FPL***Dependent variable: Binary outcome**(1, if Rural County, 0 otherwise)*

	Baseline	Controlling for Demographic (Weights = %AfAm + %Asian + %Hisp)	Population Variance Model
Energy burden	0.421 <sup>***</sup>	0.626 <sup>***</sup>	0.423 <sup>***</sup>
	(0.146)	(0.040)	(0.045)
Poverty rate	-0.129	-0.082 <sup>***</sup>	-0.130 <sup>***</sup>
	(0.119)	(0.025)	(0.036)
Log (median Income)	-6.650 <sup>*</sup>	-7.532 <sup>***</sup>	-6.848 <sup>***</sup>
	(3.504)	(0.748)	(1.076)
Constant	59.654	61.655 <sup>***</sup>	61.605 <sup>***</sup>
	(40.899)	(8.752)	(12.539)
Observations	80	80	80
Log Likelihood	-38.599	-972.738	-412.028
Akaike Inf. Crit.	85.198	1,953.476	832.056
Note:	* p < 0.10 ** p < 0.05 *** p < 0.01		

Table 7

**Summary of Diagnostic Tests for North Carolina**

Test name	Test type	Baseline Model	Demographics Model	Population Model Controlled
Autocorrelation, order = 2	Breusch-Godfrey test	0.1874**	0.1874**	0.1874**
Autocorrelation, order = 3	Breusch-Godfrey test	0.153**	0.153**	0.153**
Heteroskedasticity	Breusch-Pagan	0.4917**	0.4917**	0.4917**
Heteroskedasticity	Goldfeld Quandt	0.2411**	0.2411**	0.2411**
Functional form	Rainbow test	0.5598**	0.5598**	0.5598**
Functional form	Harvey-Collier test	0.3035**	0.3035**	0.3035**
<i>Note:</i> Do not reject since $PV > 0.05$ <p style="text-align: right;">* <math>p &lt; 0.1</math>; ** <math>p &lt; 0.05</math>; *** <math>p &lt; 0.01</math></p>				

Additionally, **Table 8** (below) shows the logit model predicted probabilities, which shows that energy burden and rural poverty accounts for the variation in inequity in North Carolina.

Table 8

**Predicted Probabilities for North Carolina**

*Dependent variable: Binary outcome*

*(1, if Rural County, 0 otherwise)*

	Baseline	Controlling for Demographic (Weights = %AfAm + %Asian + %Hisp)	Population Variance Model
Energy burden	0.604***	0.652***	0.604***
	(0.146)	(0.040)	(0.045)
Poverty rate	0.468	0.480***	0.468***
	(0.119)	(0.025)	(0.036)
Log (median Income)	0.001*	0.001***	0.001***
	(3.504)	(0.748)	(1.076)
Constant	1.000	1.000***	1.000***
	(40.899)	(8.752)	(12.539)
Observations	80	80	80
Log Likelihood	-38.599	-972.738	-412.028
Akaike Inf. Crit.	85.198	1,953.476	832.056
<i>Note:</i>	* p < 0.1; ** p < 0.05; *** p < 0.01		

## 4 CONCLUSIONS

This research seeks to quantify the impact of rurality on energy burdens and inform policy recommendations that highlight rural equity priorities in program development that support LMI communities in North Carolina. This paper examines county-level energy burdens for North Carolina using data between the years of 2015 and 2020.

The results in this paper show that North Carolina households with incomes of below 50% of the Federal Poverty Level (FPL) spend approximately 32.8% or more of their annual income on home energy bills. This research finds that energy burdens are greatest in counties where there is no photovoltaic power station such as: Avery County, Ashe County, Watauga County, Madison County, Mitchell County, Yancey County, etc. Most distinctively, compared to Georgia, North Carolina shows the largest and most clear-cut differences between rural and urban household energy burdens within the same income brackets. This notable difference suggests that rural inequity plays a much larger and more distinct role in energy burdens in North Carolina than in Georgia. A significant reason for these differences is heating costs. North Carolina has a slightly cooler climate than Georgia, which requires more heating. Many rural homes in North Carolina use bottled fuel as their primary heating source, which has tripled in price over the past 20 years. Finally, because rural North Carolinians are primarily served by rural electric cooperatives, it is essential that any solutions aimed at eliminating energy burdens include programs that can be delivered through or in partnership with rural cooperative utilities.

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## Appendix A:

*Most Energy Burdened Counties in North Carolina by Federal Poverty Levels  
(In 2022, FPL for a family of four is \$27,750)*

Rank	Counties	Rural or Urban	<50%	50%-99%	100%-124%	185%-199%
1	Avery County	Rural	43.2	23.03333333	15.36666667	8.983333333
2	Ashe County	Rural	40.6	21.63333333	14.43333333	8.433333333
3	Watauga County	Urban	40.28333333	21.48333333	14.33333333	8.366666667
4	Madison County	Rural	40.13333333	21.38333333	14.28333333	8.333333333
5	Mitchell County	Rural	39.58333333	21.08333333	14.08333333	8.233333333
6	Yancey County	Rural	39.35	21	14.01666667	8.183333333
7	Jones County	Rural	38.5	20.53333333	13.66666667	8
8	Clay County	Rural	37.76666667	20.13333333	13.41666667	7.833333333
9	Alleghany County	Rural	37.6	20.05	13.35	7.8
10	Graham County	Rural	36.88333333	19.68333333	13.08333333	7.65
11	Swain County	Rural	36.68333333	19.56666667	13.03333333	7.6
12	Macon County	Rural	36.58333333	19.5	13	7.583333333
13	Cherokee County	Rural	36.48333333	19.46666667	12.98333333	7.583333333
14	Hyde County	Rural	35.36666667	18.85	12.56666667	7.35
15	Bertie County	Rural	35.16666667	18.75	12.5	7.3
16	Gates County	Rural	35.13333333	18.73333333	12.5	7.283333333
17	Haywood County	Urban	34.95	18.63333333	12.43333333	7.25
18	Wilkes County	Urban	34.86666667	18.58333333	12.4	7.233333333
19	Surry County	Urban	34.85	18.58333333	12.38333333	7.233333333
20	Northampton County	Rural	34.78333333	18.55	12.35	7.216666667
21	Jackson County	Rural	34.66666667	18.5	12.31666667	7.2
22	Person County	Rural	34.31666667	18.3	12.2	7.116666667
23	Franklin County	Urban	34.26666667	18.28333333	12.2	7.116666667
24	Caswell County	Rural	34.18333333	18.21666667	12.15	7.1
25	Transylvania County	Rural	34.1	18.2	12.13333333	7.083333333
26	McDowell County	Rural	34.03333333	18.16666667	12.08333333	7.083333333
27	Warren County	Rural	33.76666667	18	12.01666667	7.016666667
28	Granville County	Urban	33.75	18	12	7.033333333
29	Yadkin County	Rural	33.71666667	18	11.98333333	7.016666667
30	Anson County	Rural	33.63333333	17.93333333	11.98333333	6.983333333
30	Stokes County	Rural	33.63333333	17.95	11.98333333	6.983333333
32	Hertford County	Rural	33.5	17.86666667	11.9	6.95
33	Martin County	Rural	33.41666667	17.81666667	11.86666667	6.966666667
33	Halifax County	Urban	33.41666667	17.81666667	11.86666667	6.933333333
35	Stanly County	Urban	33.23333333	17.73333333	11.81666667	6.916666667
36	Davie County	Rural	33.21666667	17.73333333	11.81666667	6.916666667
37	Beaufort County	Rural	33.15	17.7	11.8	6.883333333
38	Camden County	Rural	33	17.58333333	11.71666667	6.866666667
39	Chatham County	Urban	32.96666667	17.58333333	11.75	6.85



40	Chowan County	Rural	32.9	17.55	11.7	6.833333333
40	Greene County	Rural	32.9	17.53333333	11.7	6.816666667
40	Tyrrell County	Rural	32.9	17.55	11.68333333	6.85
43	Caldwell County	Urban	32.68333333	17.43333333	11.6	6.766666667
44	Burke County	Urban	32.66666667	17.45	11.61666667	6.783333333
45	Rutherford County	Urban	32.56666667	17.38333333	11.58333333	6.766666667
46	Currituck County	Rural	32.38333333	17.25	11.5	6.733333333
47	Sampson County	Urban	32.38333333	17.26666667	11.48333333	6.733333333
48	Edgecombe County	Urban	32.31666667	17.21666667	11.48333333	6.716666667
49	Montgomery County	Rural	32.3	17.23333333	11.48333333	6.716666667
50	Alexander County	Rural	32.28333333	17.23333333	11.5	6.7
51	Johnston County	Urban	32.15	17.15	11.43333333	6.666666667
51	Vance County	Rural	32.15	17.15	11.43333333	6.683333333
53	Perquimans County	Rural	32.08333333	17.1	11.4	6.666666667
54	Washington County	Rural	32	17.06666667	11.36666667	6.65
55	Nash County	Urban	31.96666667	17.03333333	11.36666667	6.633333333
56	Randolph County	Urban	31.81666667	16.98333333	11.33333333	6.633333333
56	Duplin County	Urban	31.8	16.96666667	11.3	6.616666667
58	Polk County	Rural	31.78333333	16.95	11.3	6.583333333
58	Henderson County	Urban	31.71666667	16.91666667	11.26666667	6.583333333
60	Columbus County	Urban	31.7	16.91666667	11.28333333	6.583333333
61	Buncombe County	Urban	31.53333333	16.81666667	11.21666667	6.55
61	Rockingham County	Urban	31.5	16.8	11.21666667	6.533333333
63	Bladen County	Rural	31.43333333	16.76666667	11.15	6.55
64	Richmond County	Rural	31.38333333	16.73333333	11.16666667	6.516666667
64	Harnett County	Urban	31.33333333	16.73333333	11.15	6.516666667
66	Union County	Union	31.3	16.68333333	11.11666667	6.516666667
67	Lincoln County	Urban	31.25	16.65	11.1	6.483333333
68	Davidson County	Urban	31.15	16.6	11.06666667	6.466666667
68	Hoke County	Urban	31.1	16.58333333	11.03333333	6.45
70	Moore County	Urban	31.03333333	16.56666667	11.05	6.433333333
71	Robeson County	Urban	30.96666667	16.5	11	6.433333333
71	Rowan County	Urban	30.96666667	16.5	11.01666667	6.416666667
73	Iredell County	Urban	30.95	16.5	11	6.433333333
74	Pasquotank County	Rural	30.83333333	16.45	10.95	6.4
75	Lenoir County	Urban	30.78333333	16.4	10.96666667	6.4
75	Orange County	Urban	30.76666667	16.4	10.91666667	6.4
77	Alamance County	Urban	30.75	16.4	10.96666667	6.383333333
78	Pamlico County	Rural	30.71666667	16.35	10.93333333	6.366666667
79	Wayne County	Urban	30.65	16.36666667	10.91666667	6.383333333
79	Lee County	Urban	30.6	16.33333333	10.88333333	6.366666667

81	Cabarrus County	Urban	30.55	16.31666667	10.83333333	6.35
82	Catawba County	Urban	30.53333333	16.28333333	10.83333333	6.35
83	Scotland County	Rural	30.46666667	16.23333333	10.81666667	6.33333333
83	Cleveland County	Urban	30.43333333	16.23333333	10.81666667	6.33333333
85	Wilson County	Urban	30.33333333	16.18333333	10.76666667	6.28333333
86	Brunswick County	Urban	29.98333333	15.98333333	10.65	6.21666667
86	Wake County	Urban	29.9	15.95	10.63333333	6.2
88	Pender County	Urban	29.85	15.91666667	10.6	6.2
89	Guilford County	Urban	29.76666667	15.85	10.56666667	6.18333333
90	Gaston County	Urban	29.68333333	15.81666667	10.56666667	6.16666667
91	Craven County	Urban	29.5	15.73333333	10.5	6.15
92	Forsyth County	Urban	29.43333333	15.68333333	10.45	6.11666667
93	Dare County	Urban	29.38333333	15.66666667	10.43333333	6.13333333
94	Carteret County	Urban	29.28333333	15.61666667	10.4	6.08333333
95	Pitt County	Urban	29.13333333	15.55	10.33333333	6.06666667
96	Durham County	Urban	29	15.48333333	10.31666667	6.03333333
97	Cumberland County	Urban	28.8	15.35	10.21666667	6
98	Onslow County	Urban	28.31666667	15.11666667	10.06666667	5.88333333
99	Mecklenburg County	Urban	28.21666667	15.05	10.03333333	5.86666667
100	New Hanover County	Urban	27.71666667	14.78333333	9.85	5.76666667

## Appendix B:

### *County-by-County Analysis of Residential Average Energy Rates in North Carolina*

County	Population	Electricity Providers	PV (Solar Plants)	Residential Rate (¢)	Residential Avg. Electric Bill
Alamance County	169,509	5	8	10.85	\$111.89/mo.
Alexander County	37,497	4	3	10.95	\$119.60/mo.
Alleghany County	11,137	2	0	12.9	\$114.63/mo.
Anson County	24,446	3	9	12.39	\$135.84/mo.
Ashe County	27,203	1	0	12.86	\$114.00/mo.
Avery County	17,557	4	0	10.96	\$104.53/mo.
Beaufort County	46,994	5	11	14.02	\$135.23/mo.
Bertie County	18,947	2	5	14.82	\$171.64/mo.
Bladen County	32,722	4	15	12.28	\$140.88/mo.
Brunswick County	142,820	3	5	12.59	\$133.47/mo.
Buncombe County	261,191	5	6	11.19	\$114.40/mo.
Burke County	90,485	6	9	10.77	\$114.72/mo.
Cabarrus County	216,453	4	6	10.71	\$114.33/mo.

Caldwell County	82,178	4	3	11.5	\$109.00/mo.
Camden County	10,867	2	3	12.2	\$151.81/mo.
Carteret County	69,473	3	0	11.59	\$121.72/mo.
Caswell County	22,604	4	5	12.17	\$134.27/mo.
Catawba County	159,551	6	18	10.66	\$113.56/mo.
Chatham County	74,470	4	12	12.32	\$138.57/mo.
Cherokee County	28,612	5	5	11.82	\$108.74/mo.
Chowan County	13,943	3	4	12.49	\$153.91/mo.
Clay County	11,231	3	2	12.2	\$111.00/mo.
Cleveland County	97,947	5	27	10.47	\$109.07/mo.
Columbus County	55,508	4	15	12.58	\$133.52/mo.
Craven County	102,139	5	9	11.89	\$125.81/mo.
Cumberland County	335,509	5	15	11.93	\$135.47/mo.
Currituck County	27,763	2	4	11.45	\$145.25/mo.
Dare County	37,009	3	1	14.42	\$143.35/mo.
Davidson County	167,609	5	6	10.88	\$119.59/mo.
Davie County	42,846	3	4	10.85	\$119.90/mo.
Duplin County	58,741	5	31	12.03	\$139.15/mo.
Durham County	321,488	5	5	11.38	\$122.25/mo.
Edgecombe County	51,472	7	8	12.42	\$138.26/mo.
Forsyth County	382,295	4	5	11.14	\$115.60/mo.
Franklin County	69,685	4	12	11.84	\$130.57/mo.
Gaston County	224,529	6	14	10.79	\$114.13/mo.
Gates County	11,562	2	3	13.72	\$162.99/mo.
Graham County	8,441	2	1	10.26	\$104.36/mo.
Granville County	60,443	6	7	11.95	\$132.33/mo.
Greene County	21,069	4	4	12.13	\$138.30/mo.
Guilford County	537,174	4	12	10.5	\$106.83/mo.
Halifax County	50,010	5	15	13.04	\$147.04/mo.
Harnett County	135,976	4	10	12.15	\$139.70/mo.
Haywood County	62,317	4	3	12.74	\$126.21/mo.
Henderson County	117,417	2	3	10.26	\$104.36/mo.
Hertford County	23,677	2	14	13.26	\$159.36/mo.
Hoke County	55,234	3	3	11.64	\$133.96/mo.
Hyde County	4,937	1	1	15.19	\$139.48/mo.
Iredell County	181,806	4	6	10.85	\$119.36/mo.

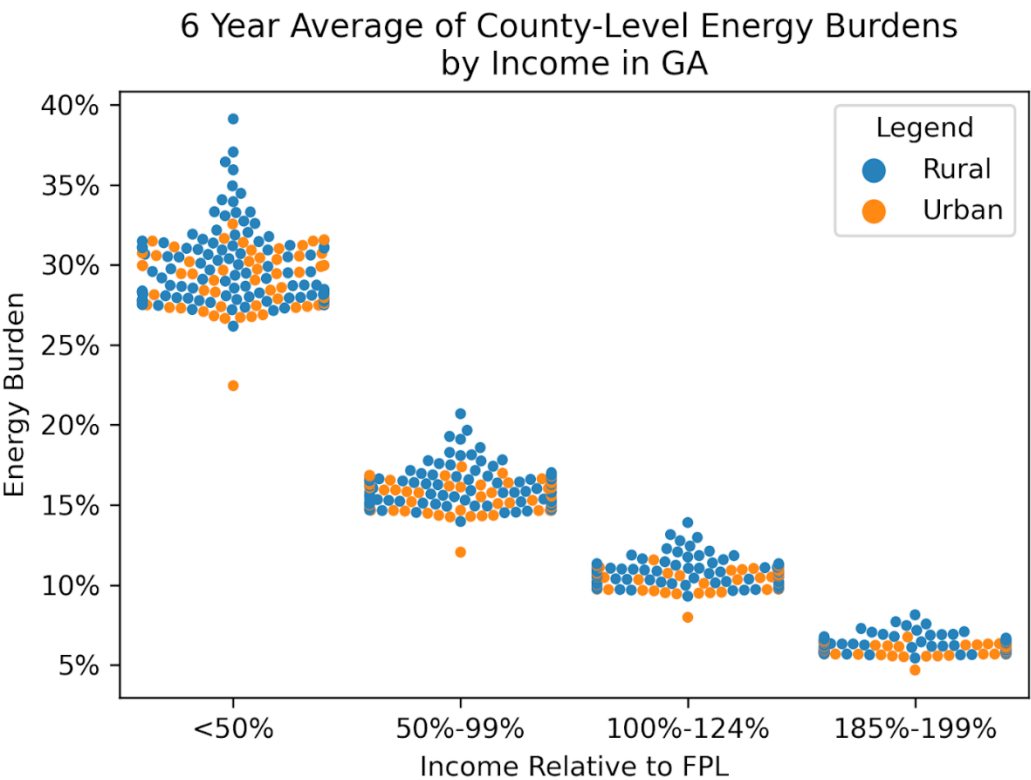
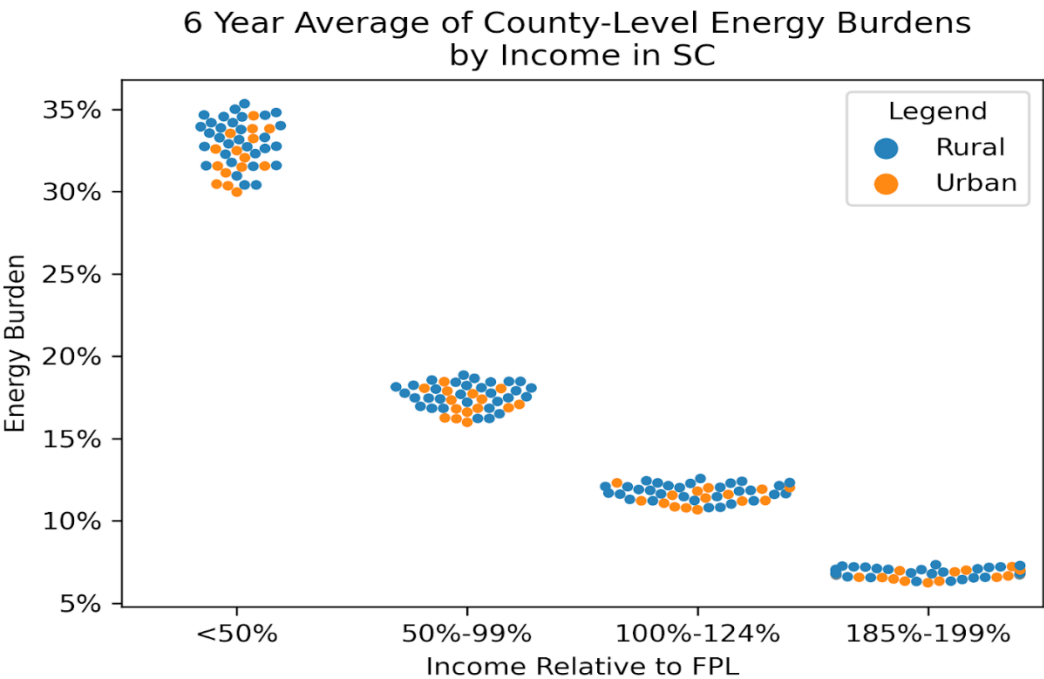
Jackson County	43,938	4	5	11.28	\$111.08/mo.
Johnston County	209,339	8	27	11.66	\$127.37/mo.
Jones County	9,419	4	6	11.67	\$126.62/mo.
Lee County	61,779	3	8	12.57	\$147.81/mo.
Lenoir County	55,949	6	13	11.69	\$129.95/mo.
Lincoln County	86,111	5	5	10.72	\$117.11/mo.
Macon County	35,858	4	3	11.04	\$108.21/mo.
Madison County	21,755	4	0	12.08	\$111.92/mo.
Martin County	22,440	6	16	12.56	\$150.67/mo.
McDowell County	45,756	3	0	10.59	\$113.63/mo.
Mecklenburg County	1,110,356	7	6	10.7	\$111.76/mo.
Mitchell County	14,964	4	0	11.93	\$114.42/mo.
Montgomery County	27,173	6	11	12.29	\$131.76/mo.
Moore County	100,880	5	9	12.36	\$135.71/mo.
Nash County	94,298	6	28	11.61	\$125.96/mo.
New Hanover County	234,473	2	3	11.6	\$126.03/mo.
Northampton County	19,483	5	15	13.53	\$160.56/mo.
Onslow County	197,938	3	4	11.69	\$127.29/mo.
Orange County	148,476	4	5	11.77	\$127.48/mo.
Pamlico County	12,726	3	1	13.4	\$132.76/mo.
Pasquotank County	39,824	3	3	12.53	\$153.92/mo.
Pender County	63,060	4	8	12.24	\$139.77/mo.
Perquimans County	13,463	2	9	12.53	\$154.61/mo.
Person County	39,490	3	10	12.41	\$137.99/mo.
Pitt County	180,742	7	10	11.66	\$126.40/mo.
Polk County	20,724	3	1	10.64	\$115.07/mo.
Randolph County	143,667	5	9	11.98	\$125.62/mo.
Richmond County	44,829	3	8	12.36	\$135.40/mo.
Robeson County	130,625	4	44	11.66	\$136.18/mo.
Rockingham County	91,010	3	8	10.58	\$112.75/mo.
Rowan County	142,088	4	14	10.64	\$113.87/mo.
Rutherford County	67,029	4	11	10.56	\$111.94/mo.
Sampson County	63,531	5	13	12.21	\$141.02/mo.
Scotland County	34,823	5	12	11.81	\$134.60/mo.
Stanly County	62,806	5	4	11.2	\$123.47/mo.
Stokes County	45,591	4	3	11.45	\$121.12/mo.

Surry County	71,783	4	4	12.75	\$130.52/mo.
Swain County	14,271	2	1	10.26	\$104.36/mo.
Transylvania County	34,385	3	0	11.96	\$112.84/mo.
Tyrrell County	4,016	1	0	11.36	\$144.48/mo.
Union County	239,859	6	7	11.4	\$125.91/mo.
Vance County	44,535	4	13	11.74	\$128.87/mo.
Wake County	1,111,761	6	11	11.7	\$127.39/mo.
Warren County	19,731	4	9	12.76	\$138.49/mo.
Washington County	11,580	2	3	12.94	\$142.42/mo.
Watauga County	56,177	3	0	12.71	\$112.43/mo.
Wayne County	123,131	4	27	11.58	\$130.84/mo.
Wilkes County	68,412	5	0	12.08	\$121.71/mo.
Wilson County	81,801	5	14	11.64	\$126.20/mo.
Yadkin County	37,667	3	5	12.74	\$130.58/mo.
Yancey County	18,069	3	0	12.03	\$111.53/mo.

Source: *Find Energy*

Appendix C:

6 Year Average of County-Level Energy Burdens by Income in South Carolina and Georgia



**Most Energy Burdened Counties in GA for  
Households at 50% Federal Poverty Level**

