Mapping Total Energy Burden in Vermont

Geographic patterns in Vermonters' thermal, electric, and transportation energy use

PREPARED BY

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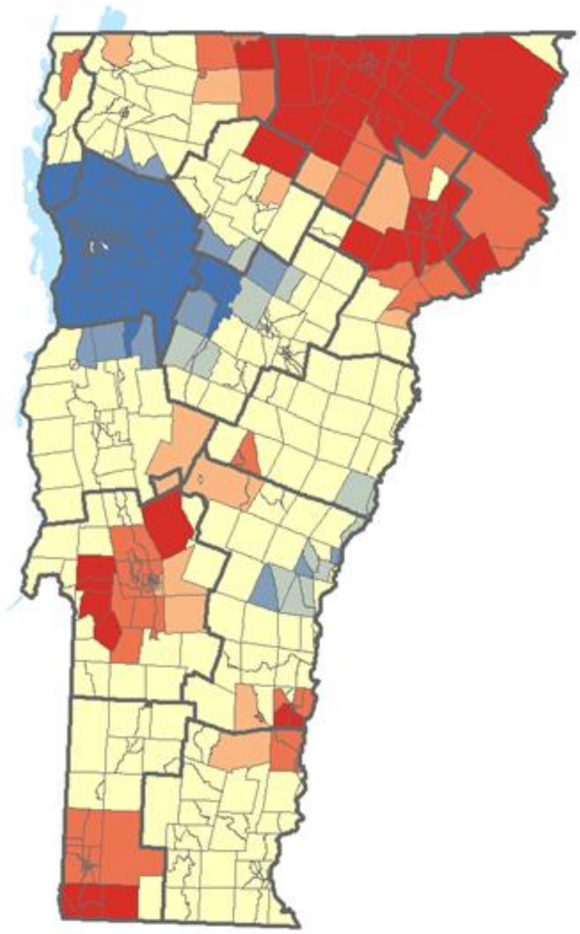
Efficiency Vermont



ACKNOWLEDGEMENTS

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Executive Summary

The primary components of total household energy use are thermal energy (heating), electricity, and transportation energy. Taken together, these "total energy" costs present a sizable financial burden to households in Vermont. The cold winter weather and the rural character of the state contribute significantly to this expense. High total energy costs are driven, in part, by building inefficiencies, automobile-dependent development patterns, and vehicle inefficiencies. In Vermont and nationwide, total energy costs can be especially burdensome for low-income households.

Efficiency Vermont commissioned this study to examine patterns in energy expenditures and burdens in Vermont communities and to understand how much Vermont residents pay for thermal energy, electricity, and transportation energy. We examined spatial patterns of energy expenditures, considering spending on thermal energy, electricity, and transportation energy (vehicle fuels). We also examined total energy expenditures: the sum of household spending on these three categories of energy use. We looked at energy spending in two ways:

- **expenditures** (average dollars spent each year)
- **burden** (spending as a percent of income for a Census block group)

Using spatial analysis, we identified communities that have high energy spending and / or high energy burdens. Efficiency Vermont might consider these communities as good opportunities for targeted efficiency programming to help reduce those high costs or burdens.

We used survey data, modeling, and actual energy use data to estimate energy spending (expressed in dollars) and burden (expressed as a percent of income) for each U.S. Census block group in the state, for each energy category: thermal, electricity, and transportation; and derived a total energy factor that combined the spending and burden of all three categories.

Census block groups roughly equate to neighborhoods: Each block group contains 600 to 3,000 residents. We derived thermal energy spending from the U.S. Census Bureau's annual American Community Survey. We estimated electricity spending from town-level electricity use data from Efficiency Vermont. We based transportation energy spending (gasoline) on vehicle miles traveled (VMT) estimates available through the U.S. Housing and Urban Development's (HUD's) Location Affordability Index. Our analysis provides the first spatially explicit estimate of total energy spending and burden for Vermont households.

We identified eight Vermont Census block groups with acutely high energy burdens. Each has an exceptionally high burden for at least one energy use type; a few have a high burden for multiple categories. Regardless of the energy use category that accounts for driving up energy burdens in these highly burdened block groups, these areas are potential starting points for targeted efficiency. That is, these communities are where some form of energy relief may be most needed and make the most difference. Markedly different spatial patterns emerged among the three categories of energy costs. Clusters of high and low spending block groups varied among thermal, electric, and transportation energy spending.

Transportation costs, for which there are few assistance programs, constituted the largest portion of energy spending, especially in rural areas. Because transportation efficiency measures are not covered in the state's energy efficiency programs, Vermonters have little assistance in reducing their transportation energy costs. Thermal energy and electricity costs were also notable, particularly in parts of St. Albans and Rutland, where combined average electricity and thermal burdens are estimated to be over 12 percent of median income. These results suggest that a substantial number of Vermont households live in fuel poverty or are in danger of falling into such poverty.[1]

Total energy burden is a powerful metric that can guide planning and implementation of energy efficiency and energy assistance programs, ensuring that we prioritize our most vulnerable communities. Long-term, comprehensive programming to reduce total energy cost and burden could provide relief for Vermont households. Given the state's lengthy experience with comprehensive energy efficiency and renewable energy programs, a carefully considered, targeted program for transportation efficiency will strengthen Vermont's ability to achieve an energy-secure future for all—and will help the state achieve its energy goals, described in its *Comprehensive Energy Plan*.[2]

[1] Definitions of fuel poverty vary, but generally households spending more than 6 to 10 percent of household income on heating and electricity costs are considered to be in fuel poverty.
[2] The *Vermont Comprehensive Energy Plan* (2011 and 2016 update) contains an overarching goal of meeting 90 percent of the state's total energy needs with renewable energy by 2050. See http://publicservice.vermont.gov/publications-resources/publications/energy_plan/2015_plan.

Introduction

A household's **total energy expenditure**—or the amount paid each year for electricity, heating, and transportation—varies widely among households and communities.[3] The proportion of household income needed to cover these expenses, or **energy burden**, also varies. Households and communities for which energy burden tends to be highest could benefit more than the average state resident from energy efficiency programs and products. People with high energy burdens may be at higher risk of health problems. There is a higher likelihood that the homes they inhabit may be kept cooler (in northern climes), which can then result in increased dampness as moisture condenses on cooler surfaces. They may sit for long periods as they commute to distant jobs or shopping.

Households for which energy costs make up a large proportion of the total household budget are typically more in need of the long-term financial relief achieved by improving the energy efficiency of the homes they occupy. But where are those households? And how can an efficiency program target them for long-lasting reductions in their energy burdens?

This report examines thermal, transportation, and electric energy costs among households in Vermont, in combination with income variables, to identify geographic areas where residents face higher average total energy expenditures and energy burdens. Characterizing energy costs is an essential step in effective program design for reducing total energy burden.

Too many low- and moderate-income Vermonters with high energy burdens may find energy costs competing with other necessities like housing, food, and medicine. To provide relief for such households, New York State has recently established in policy the goal that households will pay no more than 6 percent of income for household energy.[4].

A 2014 Vermont Law School study used a household energy burden level of 10 percent to estimate levels of *energy poverty* (also called *fuel poverty*) in the State. This does not include the energy costs of transportation.[5] Energy poverty expert Brenda Boardman notes that while fuel

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[3] Fahmy, Eldin, David Gordon, and Demi Patsios. "Predicting Fuel Poverty at a Small-area Level in England," *Energy Policy* 39, no. 7 (2011): 4370-4377. http://econpapers.repec.org/article/eeeenepol/v_3a39_3ay_3a2011_3ai_3a7_3ap_3a4370-4377.htm.

[4] http://www.nyserda.ny.gov/About/Newsroom/2016-Announcements/2016-05-19-Governor-Cuomo-Announces-New-Energy-Affordability-Policy. Household energy in this instance does not include transportation energy.

[5] Teller-Elsberg, Jonathan, Benjamin Sovacool, Taylor Smith, and Emily Laine. "Energy Costs and Burdens in Vermont: Burdensome for Whom?" Report to the Vermont Low-Income Trust for Electricity, Inc. (South Royalton, Vt.: Institute for Energy and the Environment at Vermont Law School, 2014). http://www-assets.vermontlaw.edu/Assets/iee/VLS%20IEE%20Energy%20Burden%20Report.pdf.

Under United Kingdom law, a household is considered in fuel poverty when its inhabitants are "living on lower income" and cannot keep their home warm at a "reasonable rate," often considered to be 10 percent of income.

prices and household income are factors, "the real cause of fuel poverty is the energy inefficiency of the home."[6] A study conducted by the American Council for an Energy-Efficient Economy (ACEEE) supports this observation, estimating that 35 percent of the excess energy burden of urban low-income households could be eliminated by bringing their housing stock to the efficiency level of the median household.[7] This estimate highlights the need for efficiency programs to consider energy burden in their planning and implementation. In all of this energy burden research, transportation costs are left out of energy poverty estimations. Once transportation costs are considered a factor in energy poverty, a different pattern emerges. Among other things, we can see a geo-spatial relationship that can inform how energy efficiency programs can serve people living in energy poverty.

The landscape of housing affordability is highly dependent on transportation infrastructure and the distance that residents must travel to reach essential services. Generally, housing is considered affordable when associated occupancy costs (rent, mortgage, insurance, utilities, and tax payments) comprise no more than 30 percent of total household income. Transportation costs—the cost of vehicle ownership, fuel, and maintenance—are the second greatest household expense, after housing costs. HUD's Location Affordability Index estimates combined local housing and transportation costs nationwide, and offers an interactive portal for accessing community-level data via address, city, state, and ZIP Code.[8] HUD considers these combined costs to be unaffordable when they exceed 50 percent of household income. Many housing locations appear affordable when considering only housing costs, but then become unaffordable when location and associated transportation costs are also considered.[9]

Eldin Fahmy, a British researcher specializing in poverty and the social impacts on British climate change policies, has established that the prevalence of high energy burdens varies by socio-demographic characteristics of households and individuals, and by geographic location, dwelling type, structure, and occupancy.[10] In Vermont, high electric and thermal energy burdens are most often borne by households with low incomes; but these burdens also exist in many income-earning families with young children, elderly people, and people with middle-class incomes living

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[6] Boardman, Brenda. "Fuel Poverty Synthesis: Lessons Learnt, Actions Needed." *Energy Policy* 49 (2014): 143-148. https://www.deepdyve.com/lp/elsevier/fuel-poverty-synthesis-lessons-learnt-actions-needed-BjGs0N6OGc.

[7] Drehobl, Ariel, and Lauren Ross. "Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low-Income and Underserved Communities." Research Report. (Washington, DC: ACEEE, 2016). http://aceee.org/research-report/u1602.

[8] The Locational Affordability Portal (Understanding the Combined Cost of Housing and Transportation) contains a transportation cost calculator and the Location Affordability Index at http://www.locationaffordability.info.

[9] Housing costs used in the Location Affordability Index are derived from the American Community Survey and consider mortgage or rent payments, utilities, heating and cooking fuel, and condominium or mobile home site fees.

[10] Fahmy et al., "Predicting Fuel Poverty."

in energy-inefficient homes. As a group these households typically are unable to make ends meet after paying for utilities and commuting costs.[11] Research also demonstrates that people living in locations that require automobiles for getting to workplaces and accessing essential services face relatively high transportation costs. This phenomenon leads to greater risk of foreclosure on their homes. The geo-spatial challenge, most acute for people living in rural communities, highlights both the financial instability that high energy burden can cause for families, and the degree to which transportation costs, in particular, can represent the tipping point for a household's economic security.[12]

VERMONT ENERGY BURDEN

A 2014 Vermont Law School publication analyzes energy burden and poverty in Vermont. However, the report does not consider transportation energy in the analysis. A clearer understanding of the different costs and pressures facing Vermont communities will inform how Efficiency Vermont and other efficiency programs can identify and work with vulnerable populations to ease the energy burden through targeted efficiency programs. The Vermont Law School analysis of energy burden notes that "what matters to users of energy is not the price, per se, but the size of the energy bill and how it compares to income. Energy efficiency is the tool which allows people to reduce their bills even as prices rise."

This study identifies Vermont communities where residents have a high levels of total energy spending and burden, and offers a starting point for the geographic targeting of efficiency programs.

Methods

We examined two essential patterns in total energy spending: expenditures (dollars spent annually), and burden (spending as a percent of income). Total energy expenditures are the sum of household spending on thermal energy (for heating), electricity (for power and cooling), and transportation energy. Energy burden is expenditure (total, or by category), expressed as a percentage of income. The availability and quality of data on energy expenditures vary by energy category. For instance, Efficiency Vermont has meter-level data on electric energy use. Thermal energy data, however, are more problematic. Efficiency Vermont does not have access to data on energy use for thermal sources, except for those relatively rare instances in which electricity is used for heating. We combined use data, survey data, and modeling to provide a reasonably

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[11] Teller-Elsberg et al., "Energy Costs and Burdens in Vermont."

[12] Yates, Stephanie Rozelle, Grant Ian Thrall, and Eric Hangen. "Location Efficiency and Mortgage Default," *Journal of Sustainable Real Estate* (December 2009). https://www.researchgate.net/publication/235336192_Location_Efficiency_and_Mortgage_Default_Authors.

accurate estimate of energy expenditures and energy burden for Vermont households. This analysis offers the first formally documented, spatially explicit estimate of total energy spending and burden for Vermont households.

Our unit of analysis is the Census block group. Census block groups are the smallest geographic unit for which Census data are tabulated and published. Census block groups roughly equate to neighborhoods. Rural towns might have only one or two Census block groups, whereas more urban areas, such as Burlington and Rutland, contain several block groups. Each block group contains between 600 and 3,000 people.[13] Vermont has 522 block groups. To estimate expenditures and burden for each energy category by block group, we used the following data sources:

- **Median household income.** Available through the U.S. Census Bureau's annual American Community Survey (ACS). The ACS is nationwide and addresses household-level demographics and housing characteristics. The ACS estimates median household income for every Census block group in Vermont. We used ACS data pooled from 2009 to 2013 to increase the survey sample size and reliability. These years were the most recent that contained data for all variables needed for our analysis.
- **Electric energy expenditures.** Based on use data from 2011, available through Efficiency Vermont for each of Vermont's 337 towns. We multiplied average annual household electricity use by $0.163 per kilowatt-hour (kWh), the mean cost of residential electricity in Vermont in 2011, to estimate mean spending on electricity, by town.[14]
- **Thermal energy expenditures.** Derived from the ACS (2009 to 2013). *Thermal energy* refers to energy used primarily for heating. For each Census block group, the ACS estimates the total number of households and their primary source of home heat (natural gas, oil, wood, etc.). The ACS also estimates household size (number of people) and percentages of each tenure type—renter or owner. We calculated thermal energy use based on household size, tenure percentage, and estimated household square footage. The U.S. Census Bureau's 2011 American Housing Survey reports that the national average square footage of housing per occupant is 500 square feet for households that rent their space, and 800 square feet for households that own their space. We assumed thermal energy use to be 30,000 Btu per square foot.[15] We used average household size by tenure to estimate thermal energy use for each Census block group. We estimated spending on

[13] For more information on Census blocks and block groups, see http://www2.census.gov/geo/pdfs/reference/GARM/Ch11GARM.pdf.

[14] *Utility Facts*. (Montpelier, Vt: Vermont Public Service Department, 2013). http://publicservice.vermont.gov/sites/dps/files/documents/Pubs_Plans_Reports/Utility_Facts/Utility%20Facts%202013.pdf

[15] The U.S. Energy Information Administration's 2009 Residential Energy Consumption Survey (RECS) reports that average energy consumption in New England was 50,000 Btu per square foot, inclusive of thermal energy and electricity use. The 2009 RECS also found that thermal or space heating comprised 60 percent of total energy use per household. We derived our estimate of thermal fuel use as 50,0000 Btu / square foot, times 60%, to equal 30,000 Btu / square foot.

thermal energy in each block group by calculating a weighted average, using the U.S. Energy Information Administration's (EIA's) statewide average price for each heating source,[16] and combined that price with block-level estimates of average Btu consumption and the percentage of households using each heating source (see **Appendix A** for more detail). We excluded from thermal energy analyses households that reported heating with electricity, to avoid double-counting. That is, those households' spending was already captured in the dataset of electricity use.

- **Transportation energy expenditures.** Available through the Location Affordability Index (LAI), which models annual VMT for household types for each Census block group. The VMT value is based on local land use patterns, patterns in automobile ownership, and dominant travel model to work, among other factors. Estimates for eight household types are available through the LAI (see **Appendix A**). Because an average or median estimate of VMT was not available by block group, we used the estimated VMT for a moderate-income household (one earning at least 80 percent of county median income) as a mid-range, representative value. We calculated transportation energy spending as:

$$\frac{\textit{(Census block group VMT) X (Vermont average gasoline price per gallon)}}{\textit{(27.6 miles to the gallon, Vermont average vehicle fuel efficiency)}}$$

Average gasoline costs for Vermont for 2008 to 2012 came from the EIA. We used average vehicle fuel efficiency from Vermont Agency of Transportation data.[17]

In our analysis, we calculated energy expenditures and burden for each Census block group. We estimated **total energy spending** by summing expenditures on thermal, electric, and transportation energy. We estimated **energy burden** by calculating the ratio between average expenditures and median household income for each block group and energy category (thermal, electricity, and transportation; and one category for all three, or *total energy*).

A primary objective of this project is to investigate geographic patterns in residential energy use and expenditure. We examined spatial patterns in expenditure and burden (expenditures as a percentage of median household income) in ArcGIS. We used hotspot analysis in ArcGIS to identify any clusters of Census block groups with significantly higher-than-average or lower-than-average energy expenditures. We present "hot spot" maps of spending for each category

[16] EIA residential sector energy price and expenditure estimates, Vermont: http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_prices/res/pr_res_VT.html&sid=Vermont
[17] Conger, Matt, Jim Sullivan, and Glenn McRae. *The Vermont Transportation Energy Profile*. (Montpelier, Vt.: Vermont Agency of Transportation, 2013). http://vtransplanning.vermont.gov/sites/aot_policy/files/VTEPAugust%2028%202013%20FINAL.pdf

(thermal energy, electricity, transportation), as well as total energy spending and total energy burden.

Hotspots (areas colored red on the maps below, beginning with **Figure 2**) are clusters of Census block groups that have significantly higher-than-average expenditure for thermal energy, electricity, or transportation energy; or higher-than-average total energy burden. Cold spots (areas colored blue on the maps) indicate clusters of Census block groups with significantly lower-than-average expenditures. Yellow denotes areas that are not significantly different from the statewide average. The intensity of blue and red map shading indicate certainty or confidence of the analyses: Dark blue areas are cold spots with 99 percent certainty, whereas lighter blue areas are cold spots with 90 to 95 percent certainty, meaning these areas do not differ as significantly from the statewide average.

Results

Mean annual total energy spending across all Census block groups in Vermont was $4,745. Transportation energy was the largest component of total energy spending, comprising on average 52 percent of estimated household energy expenditures (**Figure 1**). Average expenditures on electricity were estimated to be $1,105, comprising 23 percent of energy costs; and thermal energy expenditures estimated to be $1,198, comprising 25 percent of total energy costs (**Table 1**). These annual means do not capture seasonal variation in energy costs. Presumably, most thermal expenditures occur in the winter, which might create greater financial stress for households than do expenditures for electric energy that are most likely to be spread evenly over the year.

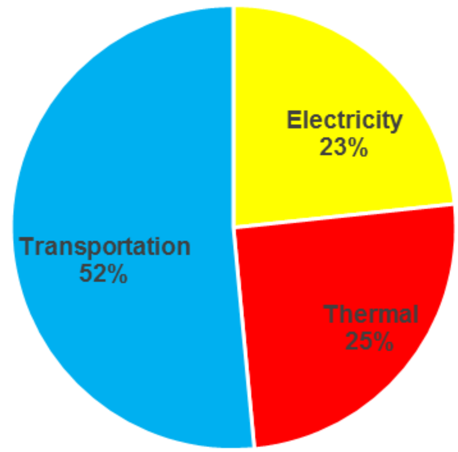

Figure 1. Components of total energy spending for Vermont households.

Table 1. Descriptive statistics by energy cost category

Energy type	Average annual household expenditure (mean + SD)	Range of average household expenditures	EAs a percent of total energy cost
Electricity	$1,105 + 163	$524-$1,686	23%
Thermal	$1,198 + 250	$381- $1,849	25%
Transportation	$2,443 + 341	$1,361-$3,012	52%
Total energy cost	$4,745 + 596	$2,681- $5,968	

THERMAL ENERGY

We estimate that on average, Vermont households surveyed spent approximately $1,200 annually to heat their homes. The five highest- and lowest-spending Census block groups are shown in Table 7B in **Appendix B**. Among the highest-spending block groups, fuel oil was the principal source of primary heat, (93 percent of households in southwest Barre and nearly 75 percent in Poultney). Propane was the primary heating source in block groups in Charlotte, Highgate Center, and Shelburne; and wood in Poultney. Among the lowest-spending block groups, four of which were in Burlington, over 80 percent of homes were heated with natural gas. Electricity was used as a heating source in these block groups for between 8 and 20 percent of households. Because we did not include households heating with electricity in our estimates of thermal energy burden (the spending is in our estimates of electric energy burden), the study might have artificially reduced estimated energy expenditures for heating in Census block groups with a high proportion of households heating with electricity.

Hot spot analysis revealed two distinct clusters of Census block groups with lower-than-average spending on thermal energy: in Chittenden County in the greater Burlington area, and in the Brattleboro area (cold spots, indicated in blue on **Figure 2**). High levels of use of relatively inexpensive natural gas (reducing cost) and the high percent of apartments (reducing estimated use) account for the lower estimates of per household energy costs in much of Chittenden County. Higher-than-average spending (red spots) are present in northern Addison County (Ferrisburgh, Monkton, and Starksboro) and central Washington County in the greater Montpelier area. High rates of homes heating with fuel oil account for thermal energy spending hot spots. Tenure also affects estimated fuel use (and thus spending). We assumed occupant-owned dwellings to be larger than those that are rented (800 square feet per person for owned homesand 500 square feet per person for rented homes). Thus, we derived high estimates of thermal energy spending from the combination of high rates of home ownership and high rates of fuel oil use. Towns such as Northfield, Williamstown, and Starksboro have very few renters.

Each cold and hot spot has an associated confidence level. For example, dark blue areas indicate block groups that are designated cold spots with 99 percent certainty (with only a 1 percent chance that spending in these block groups is not significantly less than the statewide average). Dark red spots indicate the opposite: block groups identified as hot spots, with 99 percent certainty.

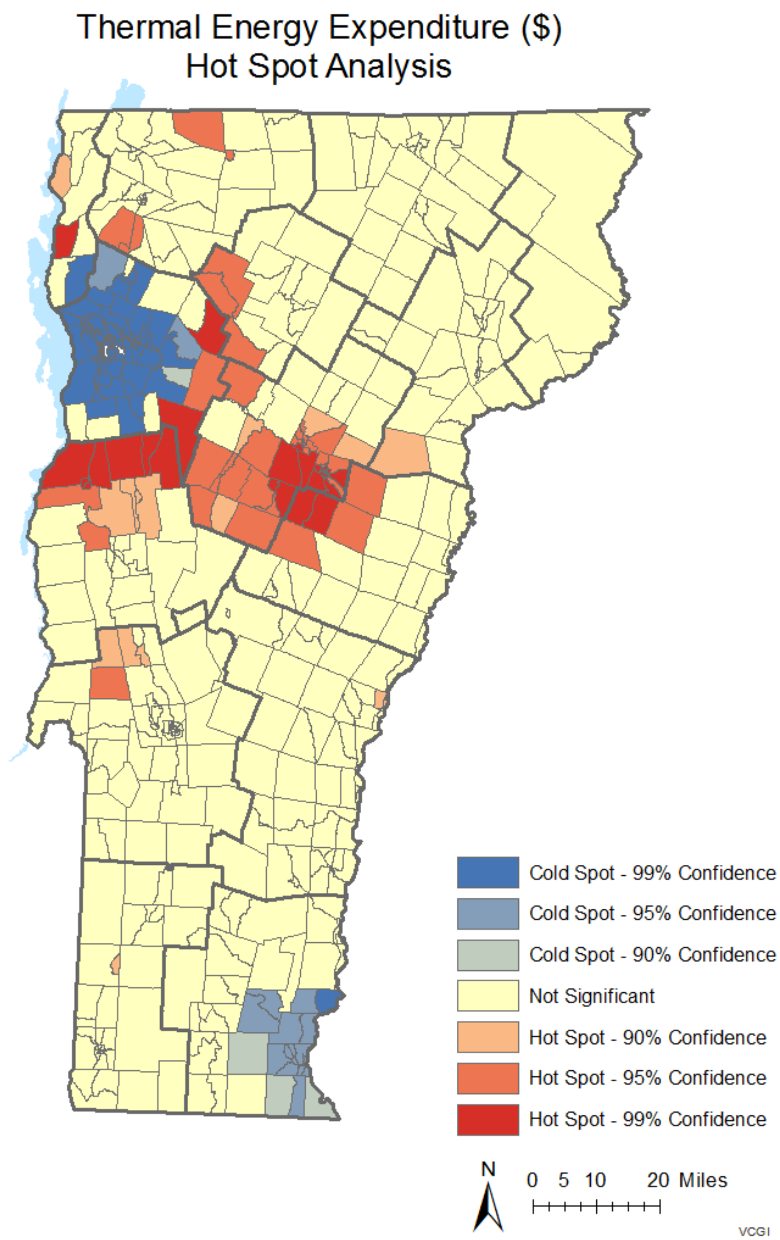

Figure 2. Thermal energy expenditure hot spot analysis, by Census block group.
Red block groups indicate clusters of higher-than-average spending on thermal energy. Blue block groups indicate clusters of lower-than-average spending.

Thermal energy burden varied eightfold among Vermont Census block groups: from less than 1 percent in Shelburne to 9.9 percent in Rutland (**Appendix B,** Table 7B). The five Census block groups spending the smallest percentage of income on thermal energy had household incomes over $70,000, and thermal energy costs of approximately 1 percent of household income. By contrast, the five towns spending the greatest proportion of household income on thermal energy all had household incomes below $30,000 and expenditures of 4 to nearly 10 percent of household income. Average thermal spending ranged by nearly a factor of 2, with approximately half of that variability due to use of natural gas (St. Albans).

Energy poverty thresholds range from 6 percent of household income to 10 percent in the literature. Regardless of these differing thresholds, with average thermal energy burdens alone approaching 5 to 10 percent, a substantial number of households in each of these five highly burdened Census block groups are in energy poverty or at high risk of becoming energy poor (**Table 2**) from their thermal burden alone. Since these estimates are derived, we have no way of knowing whether these expenditures were adequate for heating the dwelling to a comfortable or even safe temperature.

Table 2. Census block groups with highest thermal energy burden

Census block group	Thermal energy burden (% median income)	Annual thermal energy spending	Median household income
St. Albans City (northwest)	4.8	$716	$15,000
Springfield	4.9	$1,112	$22,872
St. Johnsbury (northeast)	5.0	$1,418	$28,393
Newport	5.0	$1,188	$23,688
Rutland City (southwest)	9.9	$1,705	$17,264

ELECTRICITY

Annual household electricity expenditures ranged from $524 in Averill to $1,686 in Fair Haven (**Appendix B,** Table 9B). The five highest-spending Census block groups were not among the highest-income areas in the state. None had median household incomes above $70,000 (Enosburg Falls, Dorset, Whiting, Bridport, and Fair Haven). High electricity use in these areas is not due to high rates of electric baseboard (resistance) heating; fewer than 5 percent of homes are heated with electricity in these block groups.

Hot spot analysis of electricity expenditures revealed a pattern distinct from thermal energy expenditures. While a cluster of low-spending Census block groups in Chittenden County (blue spots, **Figure 3**) was similar to the thermal picture above, the clusters of high-spending block groups in Addison County and southern Rutland / northern Bennington counties (red spots) are different. These high-spending, moderate-income block groups could be prime candidates for electric efficiency programs and financing (for example, in Addison, Bridport, Shoreham, and Peru). Block groups identified as hot spots generally had low rates of households using electricity

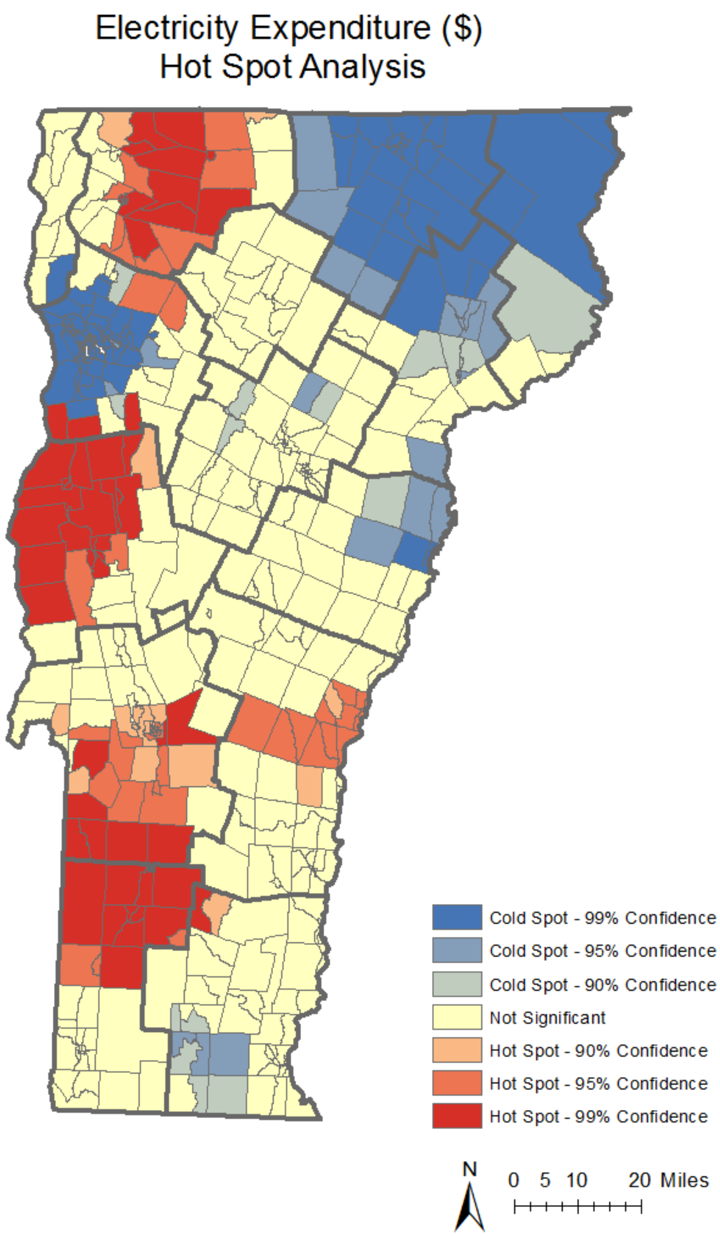

Figure 3. Electricity expenditure hot spot analysis, by Census block group.
Red block groups indicate cluster of higher-than-average spending on electricity. Blue block groups indicate clusters of lower-than-average spending.

as their heat source. Our analysis does not indicate that electric baseboard heating is a primary cause of high spending on electricity. Based on ACS estimates of primary heating energy source, none of the high spending block groups in Table 9B nor hotspot clusters in Figure 3 had high numbers of homes using electricity for heating. Northeastern Vermont was a prominent cold spot, characterized by lower-than-average expenditures.

Overall, the pattern of electricity burden (spending as a percentage of income) was similar to that observed with thermal energy burden: Spending ranged from about 1 percent in higher-income Census block groups to 7 percent in lower-income block groups. For the three highest-burdened block groups, electricity use required over 6 percent of median household income. These areas might be at high risk of energy poverty (**Table 3**).

Table 3. Census block groups with the highest electricity burden

Census block group	Electricity burden (% of median household income)	Annual electricity spending	Median household income
St. Johnsbury (downtown)	5.4	$1,057	$19,522
Colchester (east)	5.5	$1,153	$20,776
Rutland City (southwest)	6.6	$1,144	$17,264
Barre City (east)	7.1	$1,124	$15,888
St. Albans City (northwest)	7.3	$1,098	$15,000

TRANSPORTATION

Transportation energy spending varied from approximately $1,400 in Burlington to $3,000 in the rural areas of the Champlain Islands and Newbury (**Appendix B,** Table 11B). Spending tended to be highest in Grand Isle and Franklin counties. Transportation was consistently the largest component of household energy spending and burden among Census block groups, comprising between 3 and 13 percent of household incomes. The lowest-burdened block groups were high-income locations in Chittenden County (South Burlington, Burlington, and Essex Junction). Higher-burdened areas were in both rural and urban block groups (northwest St. Albans, Island Pond, and southwest Rutland), characterized by low median household income (**Table 4)**. Under such high transportation burdens, it is likely that these households are suffering from reduced mobility and access to employment and basic services.

Table 4. Census block groups with the highest transportation energy burden

Town	Transportation energy burden (% of household income)	Annual transportation energy spending	Median household income
Barre City (east)	9.8	$1,557	$15,888
Island Pond	9.9	$2,695	$27,321
St. Johnsbury (downtown)	10.0	$1,944	$19,522
Rutland City (southwest)	10.1	$1,746	$17,264
Saint Albans City (northwest)	13.0	$1,944	$15,000

As might be expected, cold spots or clusters of lower-than-average spending on transportation occur in the state's more urban areas: Burlington, Rutland, and Montpelier (**Figure 4**). Hot spots occur in rural areas such as Isle La Motte and Enosburg, but also form a ring around Chittenden

County, and to a lesser extent, Montpelier. These rings most likely illustrate the "commuter shed" of Burlington and Montpelier, demonstrating communities that are accessing the Burlington and Montpelier areas for employment and services. Pockets of high spending occurred in relatively rural and middle-income areas, suggesting that homeowners might be buying homes in rural areas with lower home prices, further from employment and amenities (restaurants and entertainment, for example). This phenomenon is known as "Drive 'til you qualify" (to a location with home prices low enough for the buyer to qualify for a mortgage).

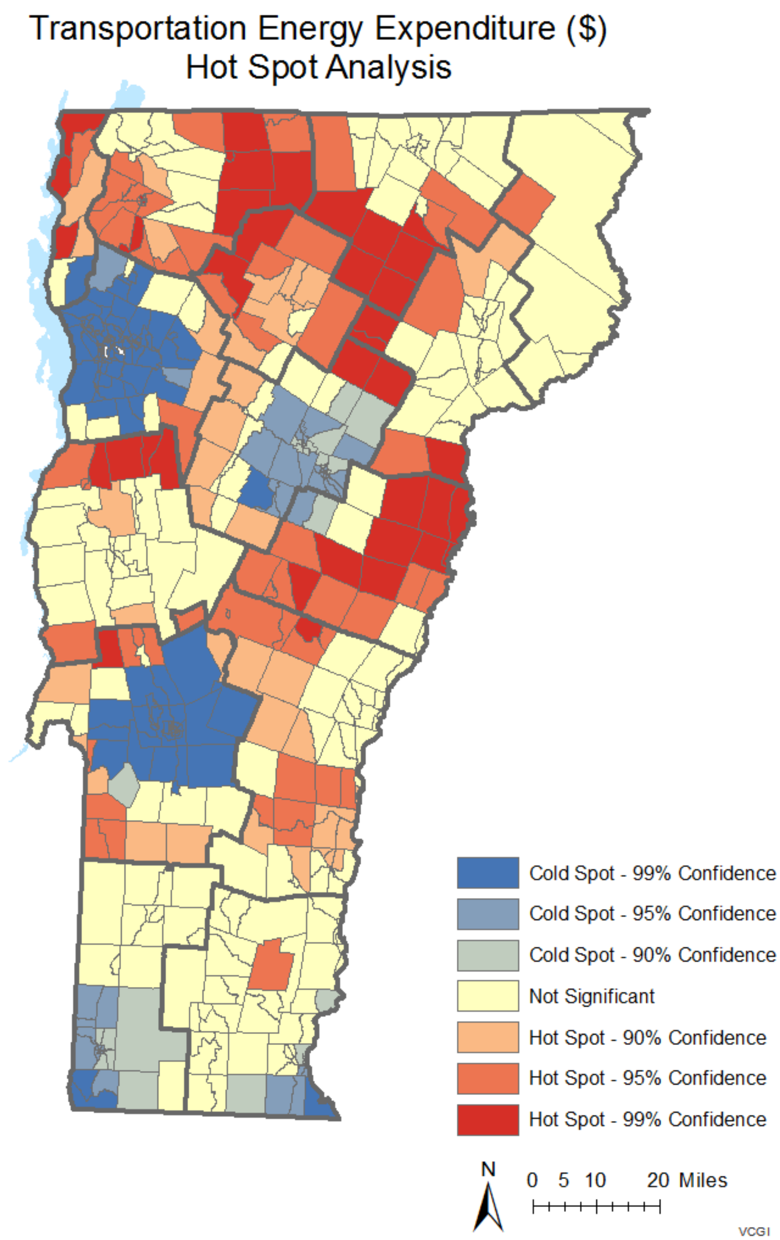

Figure 4. Transportation energy expenditure hot spot analysis, by Census block group.

Red block groups indicate clusters of higher-than-average spending on transportation energy. Blue block groups indicate clusters of lower-than-average spending.

TOTAL ENERGY SPENDING AND TOTAL ENERGY BURDEN

Total energy spending ranged from $2,600 to $5,800. Areas with the lowest total energy expenditures closely mirrored those with the lowest transportation energy costs: five Census block groups in Burlington (Appendix B, Table 13B). The highest-spending block groups, however, were communities distinct from those identified as high spenders in the other three energy categories (for example, Milton, East Berkshire, Highgate Center), suggesting that examining energy spending in total might offer new and meaningful perspectives not apparent through analysis of the specific energy categories. Hot spot analysis revealed clusters of high energy expenditures present in the Census block groups bordering Chittenden County to the north, east, and south (Figure 5).

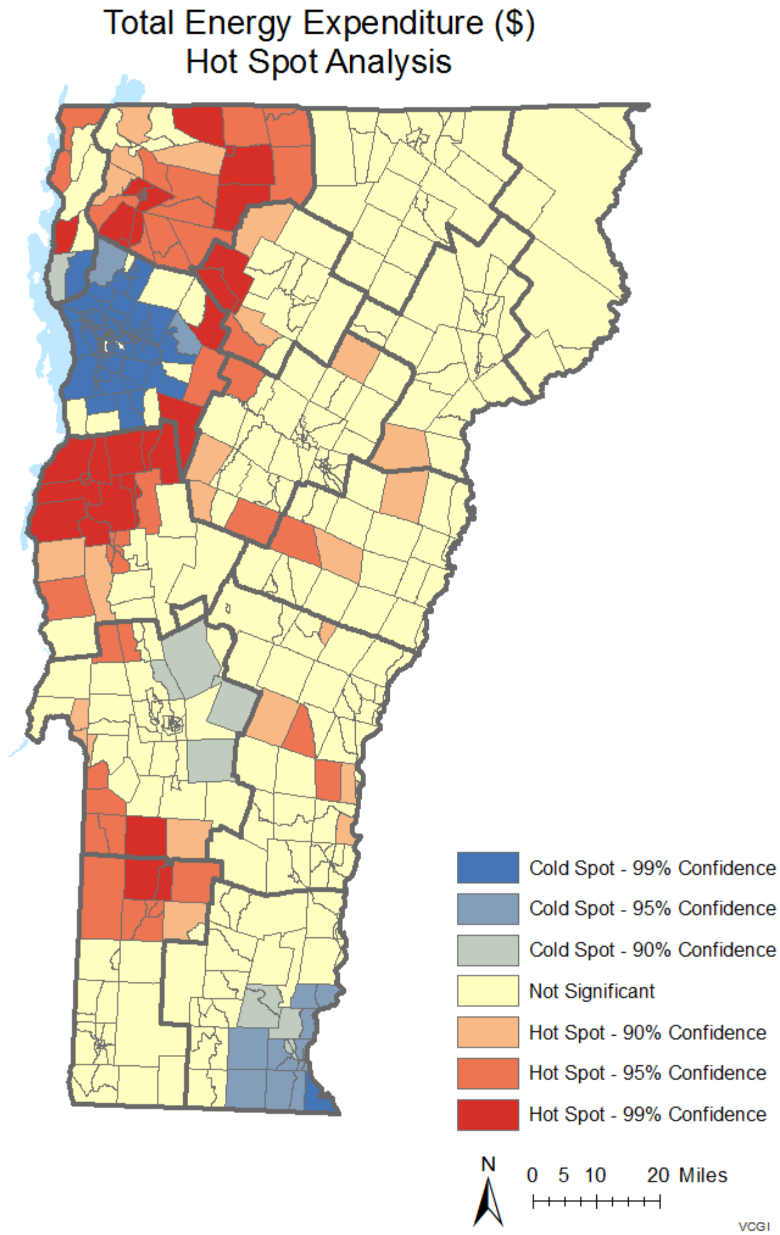

Figure 5. Total energy expenditure hot spot analysis, by Census block group.
Total energy expenditure is the sum of spending on thermal, electric, and transportation energy. Red block groups indicate clusters of higher-than-average spending. Blue block groups indicate cluster of lower-than-average spending.

Total energy burden (spending as a percentage of median household income) varied widely among Census block groups, from a low of 3 percent in South Burlington to a high of 26 percent in southwest Rutland (Table 5). Total energy spending varied by only a few thousand dollars among the lowest- and highest-burdened block groups, but median household income varied by a factor of nearly 8.

Table 5. Census block groups with the smallest and largest total energy burden

Census block group	Total energy burden (% of median household income)	Annual total energy spending	Median household income
Lowest burden			
South Burlington (east of Spear St.)	3.3	$4,477	$134,453
Burlington (Hill Section)	3.9	$3,764	$96,974
Burlington (South End)	3.9	$3,689	$93,542
Essex Junction (east of Five Corners)	4.1	$4,387	$106,000
Shelburne (lakeshore south)	4.3	$4,539	$105,461
Highest burden			
Springfield	18.8	$4,299	$22,872
St. Johnsbury (downtown)	19.0	$3,705	$19,522
Barre City (east)	21.2	$3,370	$15,888
St. Albans City (northwest)	25.1	$3,758	$15,000
Rutland City (southwest)	26.6	$4,595	$17,264

The spatial distribution of total energy burden looks quite different from the distribution of total energy expenditure: Northeastern Vermont emerged as a prominent hot spot, most likely driven by low median income and high transportation energy spending consistent with rural living (Figure 6). Both the Bennington and Rutland areas had low estimated transportation spending, but emerged as energy burden hotspots. This is likely driven by low median incomes and high levels of electricity use in parts of Rutland. Chittenden County, characterized by low total energy use and pockets of high income, was a prominent total energy cold spot.

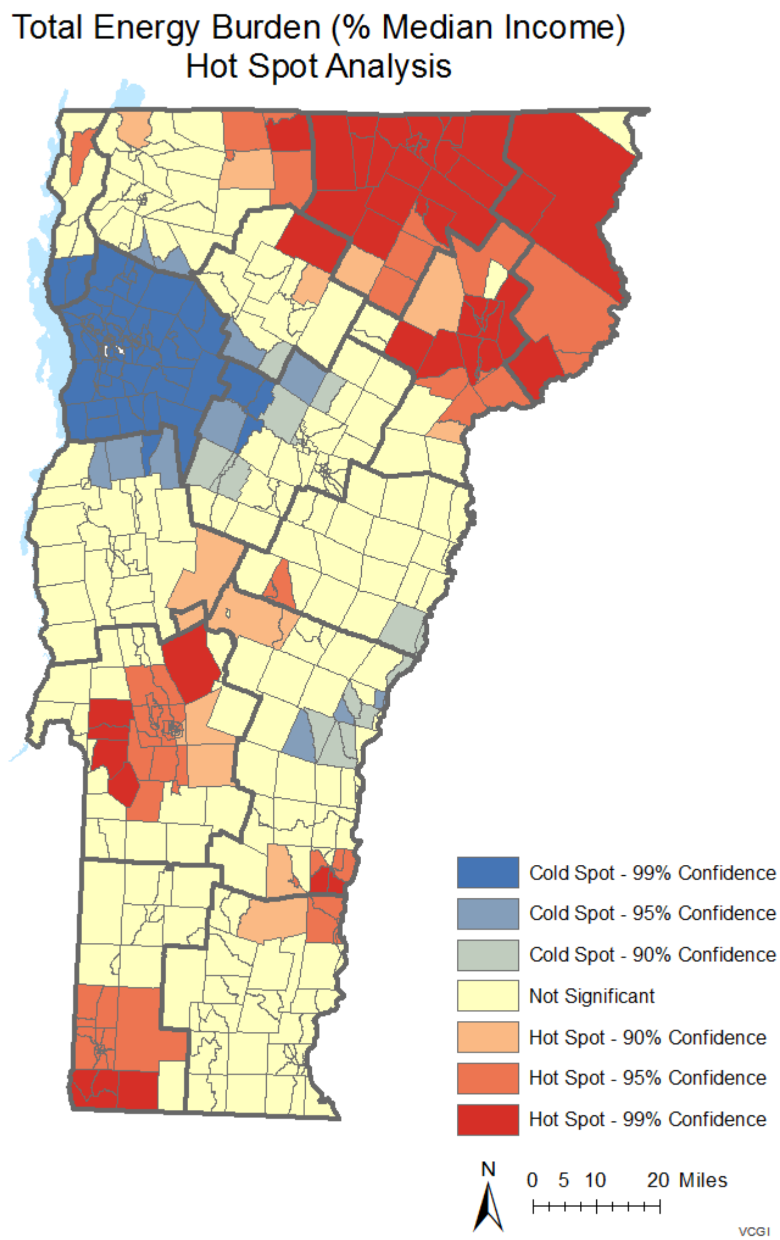

Figure 6. Total energy burden, by Census block group.
Total energy burden is the ratio of energy expenditures to household income. Red block groups indicate clusters of higher-than-average spending. Blue block groups indicate clusters of lower-than-average spending.

HIGHLY BURDENED CENSUS BLOCK GROUPS

We identified eight Census block groups as the state's most highly burdened among our four energy categories. Two Census block groups appear in all four categories: northwest St. Albans and southwest Rutland. In downtown St. Albans and southwest Rutland, combined electricity and thermal burdens are estimated to be over 12 percent of median income, putting it well above the 6 percent threshold for meeting the definition of energy poverty, and noticeably above the more conservative 10 percent threshold. In these Census block groups, comparisons of average electric and thermal costs with median income indicate a possible norm, rather than the exception, of energy poverty and energy insecurity (the absence of the uninterrupted availability of energy sources at an affordable price[18]). Regardless of which energy category drives up energy costs in these highly burdened block groups, these geographic areas are logical starting points for targeted efficiency of all three energy categories. That is, these communities are where some form of relief of energy burden is most needed.

Table 6. Census block groups with high energy burdens, all energy categories

Census block group	Energy burden (% of median household income)	Median household income	Number of appearances on this table
Thermal energy			
St. Albans City (northwest)	4.8	$15,000	4
Springfield	4.9	$22,872	2
St. Johnsbury	5.0	$28,393	1
Newport	5.0	$23,688	1
Rutland City (southwest)	9.9	$17,264	4
Electricity			
St. Johnsbury (downtown)	5.4	$19,522	3
Colchester (east)	5.5	$20,776	1
Rutland City (southwest)	6.6	$17,264	4
Barre City (east)	7.1	$15,888	3
St. Albans City (northwest)	7.3	$15,000	4
Transportation energy			
Barre City (east)	9.8	$15,888	3
Island Pond	9.9	$27,321	1
St. Johnsbury (downtown)	10.0	$19,522	3
Rutland City (southwest)	10.1	$17,264	4
Saint Albans City (northwest)	13.0	$15,000	4
Total energy			
Springfield	18.8	$22,872	2
St. Johnsbury (downtown)	19.0	$19,522	3
Barre City (east)	21.2	$15,888	3
St. Albans City (northwest)	25.1	$15,000	4
Rutland City (southwest)	26.6	$17,264	4

[18] Derived from the International Energy Agency definition of *energy security*. https://www.iea.org/topics/energysecurity/subtopics/whatisenergysecurity/.

Discussion

Our analysis revealed distinct spatial patterns in household spending for thermal, electric, and transportation energy. For the most part, areas identified as energy expenditure hot and cold spots (clusters of higher-than-average and lower-than-average expenditures, respectively) differed among energy categories. Spatial analysis is thus crucial for identifying communities and households most in need of efficiency services. There was some overlap among hot and cold spot designations across energy categories. For instance, the greater Burlington area emerged as a consistent cold spot for thermal, electric, and transportation energy spending. Multifamily housing is prevalent in this area, reducing thermal and electric energy use, and access to natural gas reduces spending even further. Also, as the state's most urban and densely developed area, VMT and transportation spending were lower, as well. Northern Addison County (Ferrisburgh, North Ferrisburgh, Monkton, and Starksboro) emerged as a consistent hot spot for thermal, transportation, and electric energy spending. These block groups are characterized by high rates of fuel oil heating and high levels of VMT. However, Monkton and Starksboro were actually part of the greater Burlington area total energy burden cold spot. Even though energy use was high in these block groups, it still comprised a smaller percentage of median income than the statewide average. We also identified parts of Franklin County as hotspots for transportation energy and electricity spending (Berkshire, Enosburg, Fletcher, and Fairfax), and for energy burden (Richford and Montgomery).

Transportation and thermal energy expenditures comprised over three-quarters of household energy costs. Although thermal energy efficiency is a required feature of Efficiency Vermont programming, implementation of programs is restricted to indirect methods for obtaining reductions in unregulated fossil fuel use, and thermal efficiency programming is newer to Efficiency Vermont's portfolio and not as robustly resourced. Transportation efficiency is largely absent from Efficiency Vermont programs.[19] Nevertheless, our analysis suggests that incorporated each into the Efficiency Vermont's portfolio of services could provide great value in reduction of energy burden. Those geographic areas where inhabitants have the greatest energy burden are an ideal target. Economic improvements from reduced total energy burden have a clear, beneficial effect on the state's economy.[20]

We identified exceptionally high average energy burdens for at least one energy category in eight Census block groups. Even with the indirect nature of thermal efficiency programming in

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[19] The Vermont Energy Investment Corporation, which operates Efficiency Vermont, has drafted a Transportation Technical Reference Manual, a prerequisite for characterizing transportation efficiency measures for evaluation, measurement, and verification under an Efficiency Vermont portfolio of programs.

[20] For a description of economic benefits from reduced energy burdens, see Teller-Elsberg et al., "Energy Costs and Burdens in Vermont."

Vermont, and the lack of transportation efficiency services, total energy burden is an important consideration for designing efficiency services for low-income households and communities.

As expected, we found that energy comprises a larger percentage of household income for lower-income households, although the actual dollar amount spent on energy might be less. Many factors affect household energy expenditures. We could not capture them all in our analysis—for example, we did not have data on house size, location, age, and condition. Income, in particular, has a complicated relationship with energy use. The Vermont Law School study noted that electricity spending tends to be higher among higher-income households, with the highest income decile spending 54 percent more than the lowest-income decile. For natural gas, used primarily as a heating fuel, the disparity is smaller, with upper-income households using 36 percent more than lower-income households heating with this fuel. Upper-income households use 30 percent more of other fuels, such as propane and oil. However, the results of the most recent Residential Energy Consumption Survey (2009) further illustrate the importance of access to efficiency. Nationally, mean household energy use per square foot is *highest* for households with income at or below the federal poverty line and *lowest* for those earning above 150 percent of the federal poverty line.[21] Thus, not only is the energy burden high for low-income households, energy use tends to be proportionally higher, too. This is likely due to the fact that low-income households tend to rent more often, live in smaller apartments or homes; these homes may also be less energy efficient.

Our analysis did not consider other costs related to transportation, such as vehicle ownership and maintenance, although these factors can be closely linked to overall energy use. These combined costs can be sizable, estimated by the Location Affordability Index to be over 30 percent of median household income for moderate-income households in many of Vermont's rural communities. For low income and single parent households, combined transportation costs are estimated to be over 50 percent of household income in many rural communities.

Higher-income households presumably can access and invest more easily in efficient technologies and home improvements (ENERGY STAR® products, insulation, weatherization) to reduce their higher energy use and cost. Further, a larger percentage of low-income households are renters who might be unable to reduce their energy costs through efficiency upgrades to their dwellings. Thus, the thermal and electric energy burdens that households experience are products of a combination of mitigating factors, like building efficiency and size. Higher-income households also have a wider variety of housing options, including options in denser, less automobile-dependent town centers.

Our results indicate that energy burden is sizable among Vermont's rural and low- and moderate-income households. Estimated burden as a percentage of income is a defensible

[21] EIA Residential Energy Consumption Survey, Table CE 1.2: http://www.eia.gov/consumption/residential/

metric that can be combined with spatial analysis to guide planning and implementation of efficiency and energy relief programs.

Appendix A: Notes on Methods

THERMAL ENERGY

Thermal energy refers to energy used primarily for heating (although it might also involve a small amount used for cooking, clothes drying, etc.). Full data on thermal energy use are difficult to acquire, since household energy use is considered confidential information by utilities and fuel providers. We used data from the ACS to estimate thermal energy use and spending, with the following formulas:

> **Average household energy use per Census block group**:
>
> [(average household size, owner occupied) X (% owner-occupied households) X (30,000 btu / square foot) X (800 square feet)] + [(average household size, renter occupied) X (% renter occupied households) X (30,000 btu / square foot) X (500 square feet)
>
> Thermal energy spending:
>
> **Average household spending per Census block group**:
>
> [(Average household use in btu) X (% households using fuel type *A*) X (average price per MMBTU fuel type *A*)] + [(average household use in btu) X (% households using fuel type *A*) X (% households using fuel type *B*) X (average price per MMBTU fuel type *B*), etc.

Our analysis considered the ACS-specified fuel types: natural gas, propane, fuel oil, coal, wood, and solar energy. Households that listed electricity as their primary source of heat were excluded from this analysis to prevent double-counting. We captured their expenditures on heating as expenditures on electricity (described below).

TRANSPORTATION

Estimates of household expenditures on transportation came from the Location Affordability Index, the most comprehensive transportation expenditure data available. This index provides estimates of annual VMT for eight household types within each Census block group. Unlike the estimates of electricity and thermal energy expenditures, which were based on survey data and actual use data, we modeled our estimates of transportation energy expenditures. The LAI models VMT for each Census block group, from local land use patterns, patterns in automobile ownership, and dominant travel model to work, among other factors.[22] The LAI uses median

[22] See Location Affordability Index, Data and Methodology: http://www.locationaffordability.info/About_Data.aspx.

income data from the 2008-2012 ACS and considers eight household types, presenting estimated VMT for each. Household types considered for each Census block group are:

- Median income family (100% median income, two commuters)
- Very-low-income individual (national poverty line, one commuter)
- Working individual (50% median income, one commuter)
- Single professional (135% median income, one commuter)
- Retired couple (80% median income, no commuters)
- Single parent family (50% median income, one commuter)
- Moderate income family (80% median income, one commuter)
- Dual professional family (150% median income, two commuters

Our analysis uses VMT estimates for a moderate income family to serve as a mid-range value representative of the Census block group.

Appendix B: Tables and Figures

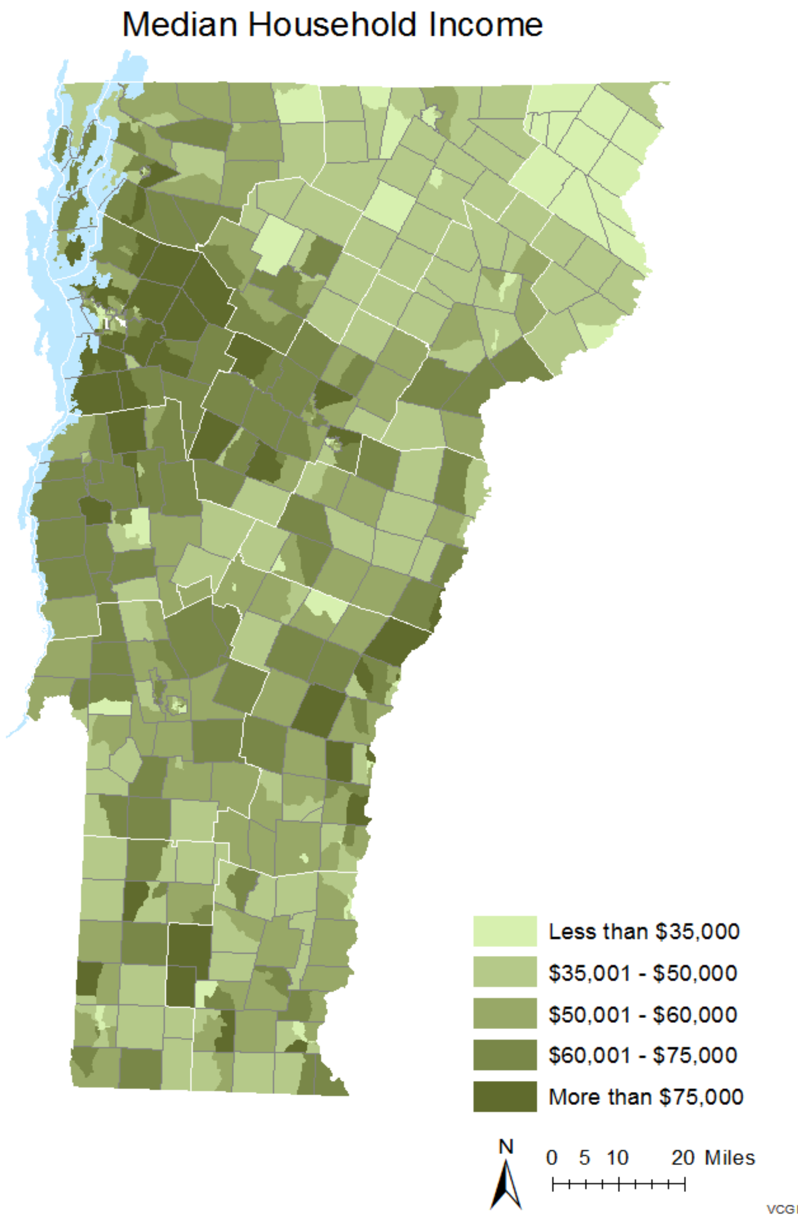

Figure 7B. Median income by census block group in Vermont.

Table 7B. Census block groups with the highest and lowest household thermal energy expenditures

Census block group	Annual thermal energy spending
Lowest spenders	
Colchester (east)	$381
Burlington (downtown, south)	$470
Burlington (downtown, east)	$475
Burlington (Old North End, west)	$481
Burlington (Old North End, east)	$493
Highest spenders	
Poultney	$1,739
Charlotte	$1,745
Highgate Center (south)	$1,752
Shelburne (lakeshore, south)	$1,754
Barre	$1,849

Table 8B. Census block groups with the lowest and highest thermal energy burden

Census block group	Thermal Energy Burden (% of median income)	Annual thermal energy spending	Median household income
Smallest burden			
Shelburne	0.7 %	$789	$105,461
South Burlington (east of Spear St.)	0.8 %	$1,074	$134,453
Burlington (South End)	1.0 %	$729	$74,306
Burlington (South End, lakeshore)	1.0 %	$926	$93,542
Burlington (South End, south of Flynn Ave.)	1.0 %	$728	$72,479
Largest burden			
St. Albans City (northwest)	4.8%	$716	$15,000
Springfield	4.9%	$1,112	$22,872
St. Johnsbury (northeast)	5.0%	$1,418	$28,393
Newport	5.0%	$1,188	$23,688
Rutland City (southwest)	9.9%	$1,705	$17,264

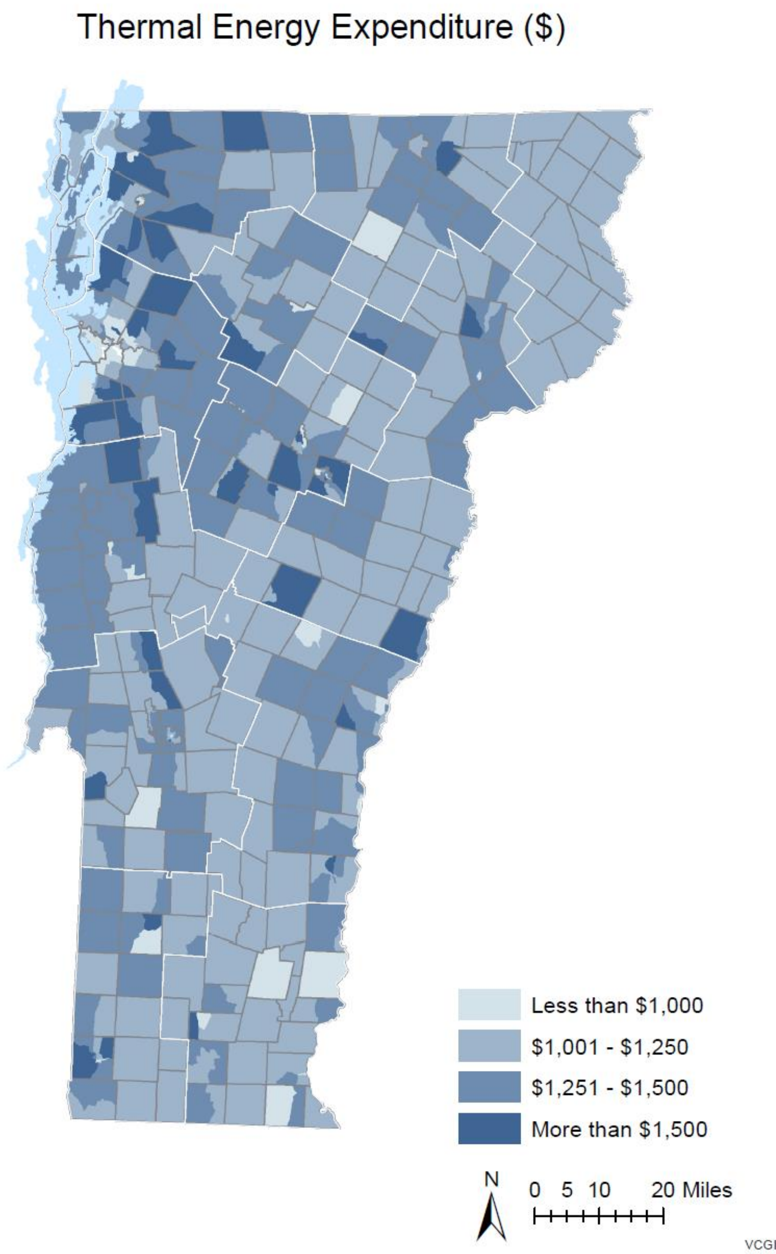

Figure 8B. Annual household thermal expenditure, by Census block group.

Table 9B. Census block groups with the lowest and highest household electricity expenditures

Census block group	Annual electric energy spending
Lowest spenders	
Averill	$524
Morgan	$668
Glover	$713
North Hero	$727
Wells River	$736
Highest spenders	
Enosburg Falls	$1,551
Dorset	$1,601
Whiting	$1,648
Bridport	$1,657
Fair Haven	$1,686

Table 10B. Census block groups with the lowest and highest electricity burden

Census block group	Electric Energy Burden (% median household income)	Annual electricity spending	Median household income
Smallest burden			
South Burlington (east of Spear St.)	0.8	$1,071	$134,453
Burlington (Hill Section)	0.9	$850	$96,974
Burlington (South End lakeshore)	0.9	$850	$93,542
West Wardsboro	1.0	$885	$91,250
Fayston	1.0	$845	$83,000
Largest burden			
St. Johnsbury (downtown)	5.4	$1,057	$19,522
Colchester (east)	5.5	$1,153	$20,776
Rutland City (southwest)	6.6	$1,144	$17,264
Barre City (east)	7.1	$1,124	$15,888
St. Albans City (northwest)	7.3	$1,098	$15,000

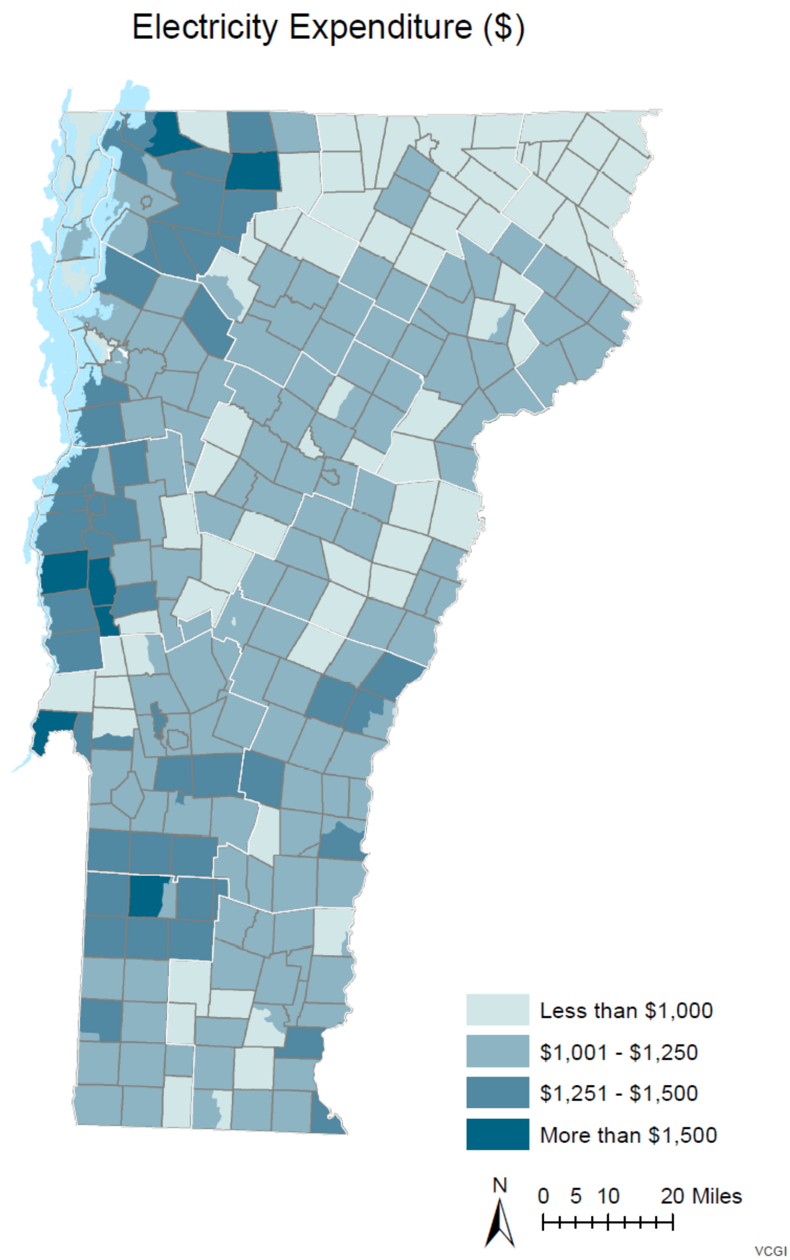

Figure 9B. Annual household electricity expenditure, by Census block group.

Table 11B. Transportation energy spending by Census block group

Census block group	Annual transportation energy spending
Lowest spenders	
Burlington (downtown, south)	$1,361
Burlington (Old North End, central)	$1,372
Burlington (Old North End, east)	$1,383
Burlington (Old North End, east)	$1,387
Burlington (Old North End, northeast)	$1,405
Highest spenders	
Newbury	$2,954
Isle la Motte	$2,961
Alburgh (south)	$2,972
North Hero	$2,997
Alburgh (north)	$3,012

Table 12B. Census block groups with the lowest and highest transportation energy burdens

Census block group	Transportation energy burden (% of household income)	Annual transportation energy spending	Household income
Smallest burden			
South Burlington	3.3%	$2,332	$134,453
Burlington (Hill section)	3.9%	$1,932	$96,974
Burlington (South End, lakeshore)	3.9%	$1,913	$93,542
Essex Junction (east of Five Corners)	4.1%	$2,174	$106,000
Shelburne (lakeshore, south)	4.3%	$2,319	$105,461
Largest burden			
Barre City (east)	9.8%	$1,557	$15,888
Island Pond	9.9%	$2,695	$27,321
St. Johnsbury (downtown)	10.0%	$1,944	$19,522
Rutland City (southwest)	10.1%	$1,746	$17,264
St. Albans City (northwest)	13.0%	$1,944	$15,000

Table 13B. Census block groups with the lowest and highest total energy expenditures

Census block group	Annual total energy spending
Lowest spenders	
Burlington (downtown, south)	$2,681
Burlington (Old North End, east)	$2,725
Burlington (Old North End, west)	$2,749
Burlington (Old North End, central)	$2,770
Burlington (downtown, east)	$2,797
Highest spenders	
Milton	$5,784
East Berkshire	$5,791
Highgate Center (north)	$5,833
Highgate Center (south)	$5,897
Charlotte	$5,968

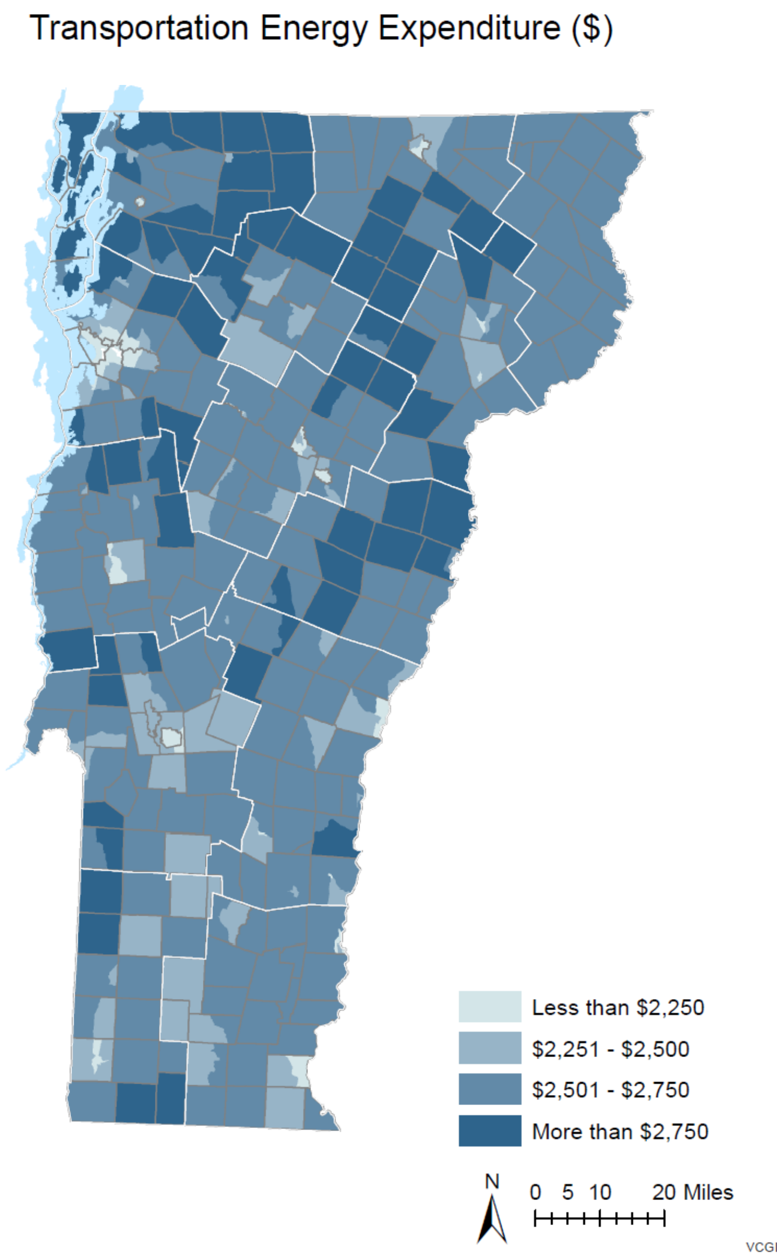

Figure 10B. Annual household transportation expenditure, by Census block group.

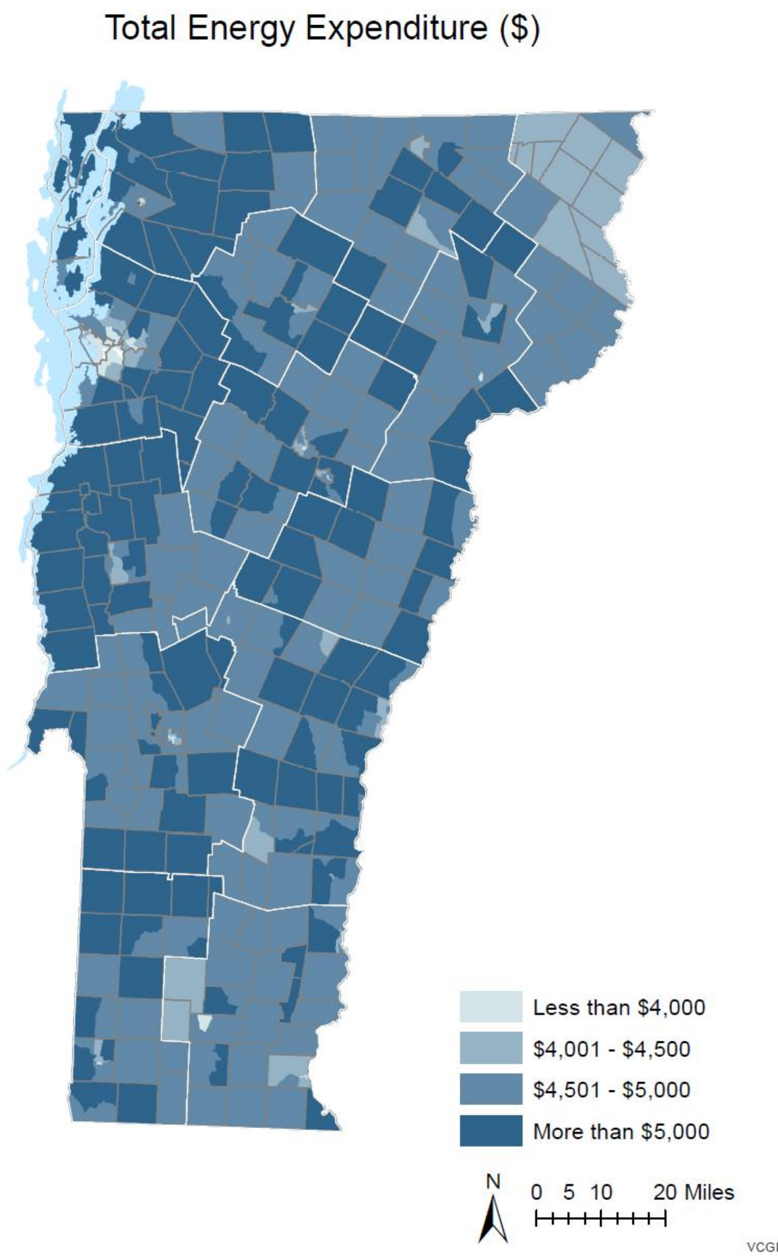

Figure 11B. Annual total household energy expenditures, by Census block group.

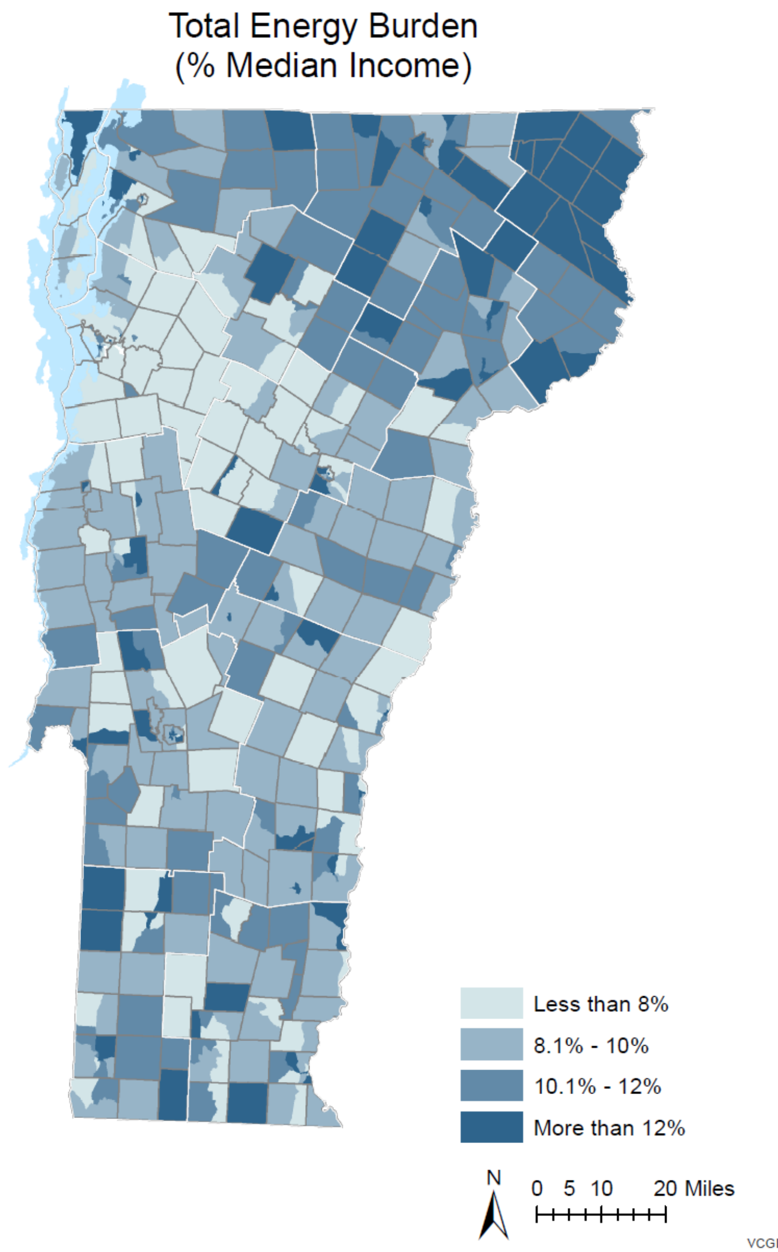

Figure 12B. Annual total household energy burden, by Census block group.