Energy Heating Methods

And

Associated Risk of Poverty

by

Aaron Murphy

Capstone submitted to fulfill the requirements for the degree of Bachelor of Science in Geography.

Marshall University

Huntington, West Virginia

May 2020

Abstract

With climate change becoming an ever-increasing threat, the state of Virginia is beginning to look at the way citizens consume energy. The type of energy households use is an important facet as different forms of energy impacts the environment as well as the economic conditions of an individual. The purpose of this paper is to find if a correlation exists between the heating methods a household uses and poverty through an examination of literature and US Census Bureau data. An OLS (Ordinary Least Squares) and a GWR (Geographically Weighted Regression) model is preformed and shows a strong correlation exists between kerosene heat and the poverty rate. Given this, GWR provides insight to where the highest rates of poverty exist allowing the state government and public health groups to target areas that are more impoverished.

Introduction

In recent years discussions have increased about the detrimental impacts that the burning of fossil fuels causes to the Earth's environment. The massive influx of CO2 emissions into the atmosphere has been linked as a contributing to increased anthropogenic warming. With this in mind – local, state, and the federal government have turned toward renewable resources in the generation of energy. The transition from fossil fuels toward renewable resources has been slowly adopted through time. This capstone will look at the various forms of heating methods and the associated impacts on poverty in the state of Virginia. This is especially important due to the increasing promotion of renewable energy sources in households across the United States. The transition from fossil fuels to renewable sources in the home heating aspect has much to grow from. The focus on renewable energies will be presented first in the literature review followed by the connection of method of energy use to poverty.

Literature Review

The threat of anthropogenic warming continues to increase worldwide due to increasing amounts of C02 emissions. Many local and national governments have forged ahead pushing for the adoption and development of alternative forms of energy to curb C02 emissions given that certain forms of fossil fuels burn cleaner than others. The following review of literature suggests that while the push for the adoption of renewable energy lowers C02 emissions there are significant obstacles which can hinder development including the current high use of fossil fuels in households and the rate of income of the household. In addition, relative low participation amongst low-income households in energy efficiency programs has limited wider adoption.

Where We're Heading

The US must be at the forefront of energy development given that the United States consumes nearly 20 percent of all energy produced worldwide. Aslani, Alireza, and Kau-Fui V. Wong (2014) analyzed renewable energy development within the United States, evaluating the cost, federal government promotion, and energy operation expenditures utilizing the Department of Energy's energy action plan for renewable development through 2030. The author's system dynamic model proposes that renewable energy will constitute 600,000 GWh of electricity generated by 2030. There are many renewable methods that exist which combine to make up the 600,000 GWh. Daim, Tugrul, et al. (2012) signified significant increases in certain forms of renewable energy production in the United States. Their growth curves project significant movement over the decade. Biomass energy is indicated to be the fastest growing renewable through the mid-2020s, biomass is followed by geothermal and wind energy. They project that renewable energy will make up 14.7% of total energy production by 2023 – which is significantly under federal generation goals; even with the US federal government promotion of wind and solar energy. Therefore, significant reliance is still placed on fossil fuels.

Renewables' Development Dilemmas

The United States has promoted wind and solar energy over other forms through the form of tax credits and subsidies. The relative strength of local, state, and federal institutions has meaningful impacts on the utilization of green energy. Bhattacharya, Mita, et al. (2017) linked the strength of institutions with the development of renewable energy in 85 developed or developing countries across the World. The authors determined that the strength of state institutions have significant impact on the overall consumption and development of renewable energy. These combine to promote sustained economic growth – a strong state combined with high renewable consumption has a net negative impact on CO 2 emissions and a positive impact on sustained economic growth. Emissions are lessened when institutions are strong and promote the adoption of renewable energies. However, a growing economic isn't always beneficial to the environment as a whole nor to the population. Bulut (2019) shows that economic growth and income inequality creates a recipe which fosters environmental degradation. The research indicates that the Environmental Kuznet Curve (EKC) is valid for the United States – as the economy grows more fossil fuels are utilized until a specific threshold is crossed; in the United States this threshold was crossed in the mid-2000s as the US government began to invest more heavily into subsidies for solar and wind energies. Bulut indicates, "From 2004 to 2017, the shares of wind and solar energy consumption in total energy consumption increased from 2.33% to 21.27% and from 0.96% to 7.02%, respectively. Awareness for solar and wind energy in the USA and the declines in costs of wind and solar energy appear to have critical roles in these remarkable increases." (p. 14568).

Intriguingly, disagreement on whether EKC is valid for the United States exists. In 2017, Dogan, Eyup, and Ilhan Ozturk researched the behavior of income, renewable energy consumption, fossil fuel energy consumption and the associated relations with CO 2 emissions for the United States. In their study which utilized data from 1980 to 2014 they found, "the EKC hypothesis is not valid for the USA since the signs of coefficients on the real income and the quadratic income are negative and positive, respectively" (p. 10853). The authors did find a correlation that exists in energy usage; they found that for every one percent rise in renewable energy consumption CO 2 emissions decreased by 0.09%. A one percent rise in fossil fuel use increased emissions by 1.04%.

Transitioning toward renewable energy from fossil fuels is often fraught with opposing factors. Greiner, Alfred, et al. (2014) gain insight to when the optimal time to transition from non-renewable energy to renewable is, and what fiscal policy is most appropriate to facilitate the transition. The authors show that the current production and investment in renewable production is a significant caveat in future energy transitions. The current high utilization of fossil fuels indicate that emissions will initially be extremely large before leveling off and declining as society beings to transition to renewable methods.

The transition to renewable energy can be dampened by serious cost barriers. (2019) show the impact of renewable energy development in European countries; the authors linked the risk of household poverty with the promotion of certain renewable energies. They found that solar and hydroelectric had little impact on household poverty, however, increased natural gas use correlated to higher rates of poverty due to the increased costs associated with it. It is argued that households which are at a higher risk of poverty need federal subsidies to help mitigate costs associated with transitioning to renewable energy from cheaper fossil fuels.

According to Xu and Chen energy inequality is a problem for low income households; the ownership of energy efficient products is far more limited with lower income households than those with higher incomes. "only 5.5% of low-income households have received assistance in bill payment or appliance repair. LIHs also have lower participation rates in the majority of EE programs, especially those with higher upfront investment" (p.772).

Incentivizing Development

Public engagement is important in promoting stronger environmental protections and in the development of alternative methods of energy. Goldfarb, Jillian L., et al. (2016) review public support for federally sponsored renewable energy credits across the United States; the authors hypothesized that the closer one is to a fossil fuel power plant, such as coal, the more likely the public would be to support tax credits whereas those nearer to a renewable energy generation site would be less inclined to support the extension of renewable credits. They tested their hypothesis by using regression models. In these models it is found that educating the public on the adverse health impacts of coal; the higher public support is for investments into renewable energy.

Data and Methods

Introduction

To gain a better picture of the participation of private and public sectors within the development of energy sources it is important to review legislation which has been passed into law and the specific data associated with its implementation. In 2009 the United States implemented a program associated with the American Recovery and Reinvestment Tax Act (ARRTA). The program's intention is to invest into renewable energy development projects across the United States. It's also required to look at the effects of energy use on low-income households. The data utilized will be from the US state of Virginia. Of note is that the state of Virginia currently suffers from a critical housing shortage, especially across the northern portion of the state near the District of Columbia. As recently as September 2019 the Virginia governor signed an executive order establishing an agreement with Dominion Power to cover 30% of

Virginia's overall electricity through renewable resources by 2022. Which would be a marked increase over current levels.

The analysis of the data presented will help to answer the fundamental questions presented; is there a relationship between energy use and income disparities? To help answer these questions - I have collected various data utilizing the Department of Treasury which keeps track and helps fund energy projects across the United States, the US census which presents population data and the types of energy utilized by households. These will help shed light on the adoption and implementation of various energy sources and can help quantify the impact on households.

ARRTA

According to the US Treasury Department as of March of 2017 the §1603 ARRTA program has funded 105,927 projects. The total government funding is $25.7 billion; the private-public (regional, state, and federal) investment in ARRTA projects is estimated to be $93.8 billion. The capacity of projects completed through March 2017 is 34.5 Gigawatts, and the annual electricity generation from all funded projects is projected to be 91.2 Terawatt-hours; or 9.12×10^{16} Gigawatt-hours.

Total Projects:	105,972
Total Funding:	$25.7 Billion
Estimated Private-Public Funding:	$93.8 Billion
Capacity of Completed Projects:	34.5 GW

Annual Electric Generation:	91.2 TwH

Table 1: §1603 ARRTA program statistics March 2017. Data provided by US Dept. of Treasury.

Approved applications submitted for funding from the ARRTA program can fund technology such as biomass, fuel cells, geothermal, hydropower, hydrokinetic, microturbine, solid waste, solar, and wind.

BioMass	Geothermal	Other	Wind	Non-Res. Solar	Res-Solar
168	163	564	1,026	19,889	84,162

Table 2: Number of projects funded by the ARRTA Program March 2017. Data provided by US Dept of Treasury.

BioMass	Geothermal	Other	Wind	Non-Res. Solar	Res-Solar
1,053	764	1,091	12,995	8,928	890

Table 3: Number of awards granted by the ARRTA Program March 2017. Data provided by US Dept of Treasury.

Total Funding	Number of Projects	Total Capacity
$95.3 Million	90	139.96 Megawatts

Table 4: The US State of Virginia statistics for the ARRTA Program March 2017. Data provided by US Dept of Treasury.

The State of Virginia

The 2010 population in Virginia had surpassed 8 million; 8,001,024 with strong growth in northern Virginia (American FactFinder, 2010). The median income was $61,406 as of 2010 which increased to $68,766 as of 2017. Five-year estimates (2013-2017) by the American Community Survey, US Census breaks this down further; 17.1% of households in the entire state report incomes of less than $24,999. With the need for housing increasing across Virginia; the state and local governments have increased permits for low-income housing. The adaption of renewable energy in low-income housing is a cause for much research.

The US census provides data with estimates on household heating methods:

Fuel Type	Owned	Rental
Utility Gas	749,138	285,632
Bottled; LP Gas	114,157	24,665
Electricity	994,768	680,157
Fuel Oil	119,414	35,471
Coal	1,585	584
Wood	63,622	14,519
No Fuel Used	5,915	6,084

Table 5: The US State of Virginia 2017 Household Energy Method. Data provided by the US Census.

The outlined data can be used to gauge the development of energy at the state level, and it shows a need to increase the development of more efficient technologies – the partnership

Method

The number of households in the state of Virginia will be statistically analyzed to see the current trends in household heating methods; presenting the numerical data in a visual way through mapping will enable easier analysis. This energy data will then be compared with more local data within ArcGIS to see which areas in Virginia need to be targeted with funding through either private and public investments (ie: ARRTA program/VA State government). Finding where high population exists in combination with higher poverty rates will show where more investments are needed. This will be done by gathering local county population, income, and energy use data from the US Census Bureau and running a series of Geographically Weighted Regressions (GWR) on the data. The dependent variable in will be the poverty rate/income, with the explanatory variables being type of energy used.

Expected Results

The anticipated results that I expect upon completion of this capstone are that households which utilize natural gas and wood heating sources are likely to have higher rates of poverty given the findings by Pereira, Diogo Santos, et al. (2019).

Analysis and Results

Total Number of Households, Income, and Poverty

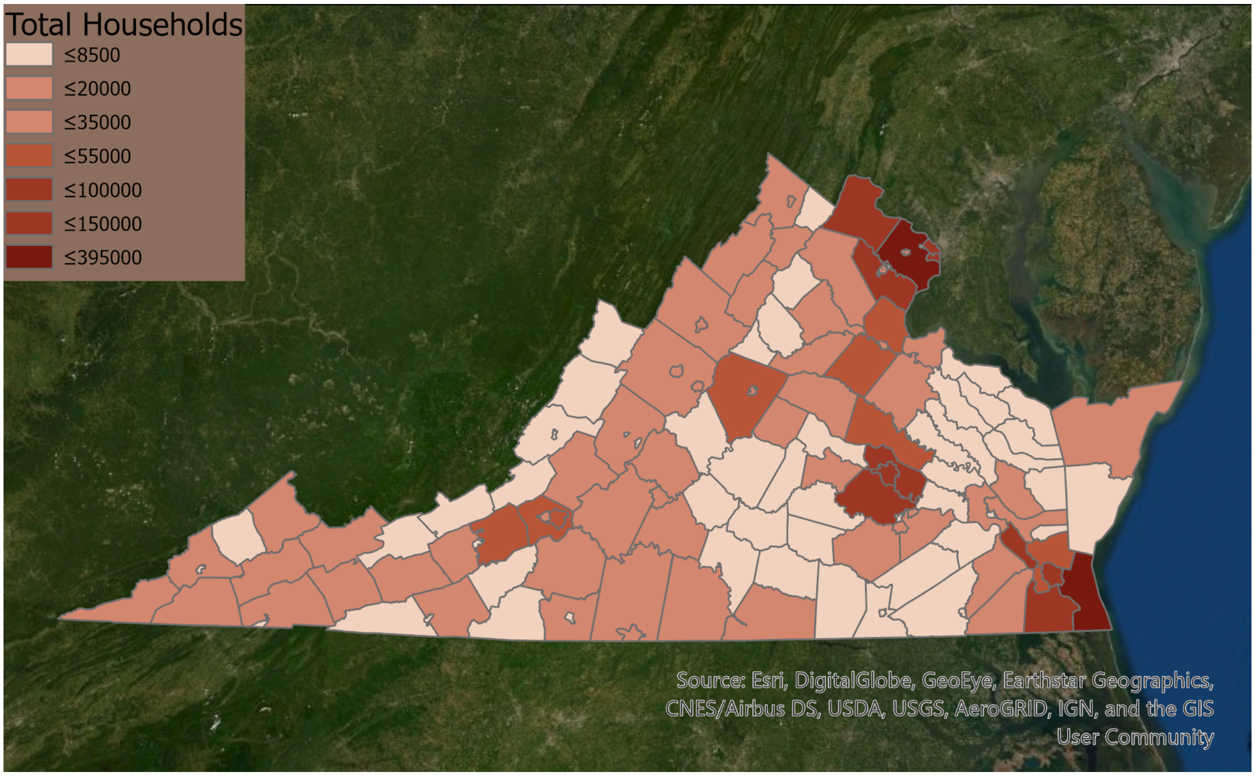

Fig 1: Total Households in Virginia (2017).

The number of households in Virginia show clustering in the urbanized areas of Virginia, particularly in the southeast Tidewater, around the state capital of Richmond, and in the Washington DC region of northern Virginia. This shows some correlation with the poverty rates in Virginia. There is significant spatial clustering in the western and southern portion of the state; focused especially on the Shenandoah Valley, the Appalachian plateau, the southern Piedmont as seen in Fig 2. These are areas where the population is lowest, the number of households' number below ~18,000. There is a notable exception to this primarily found in the Tidewater independent cities of Norfolk, Virginia Beach, Chesapeake, and Newport News in addition to Virginia's capital of Richmond where poverty rates range from 20% to 25%. These areas are heavily urbanized with a significantly high number of households.

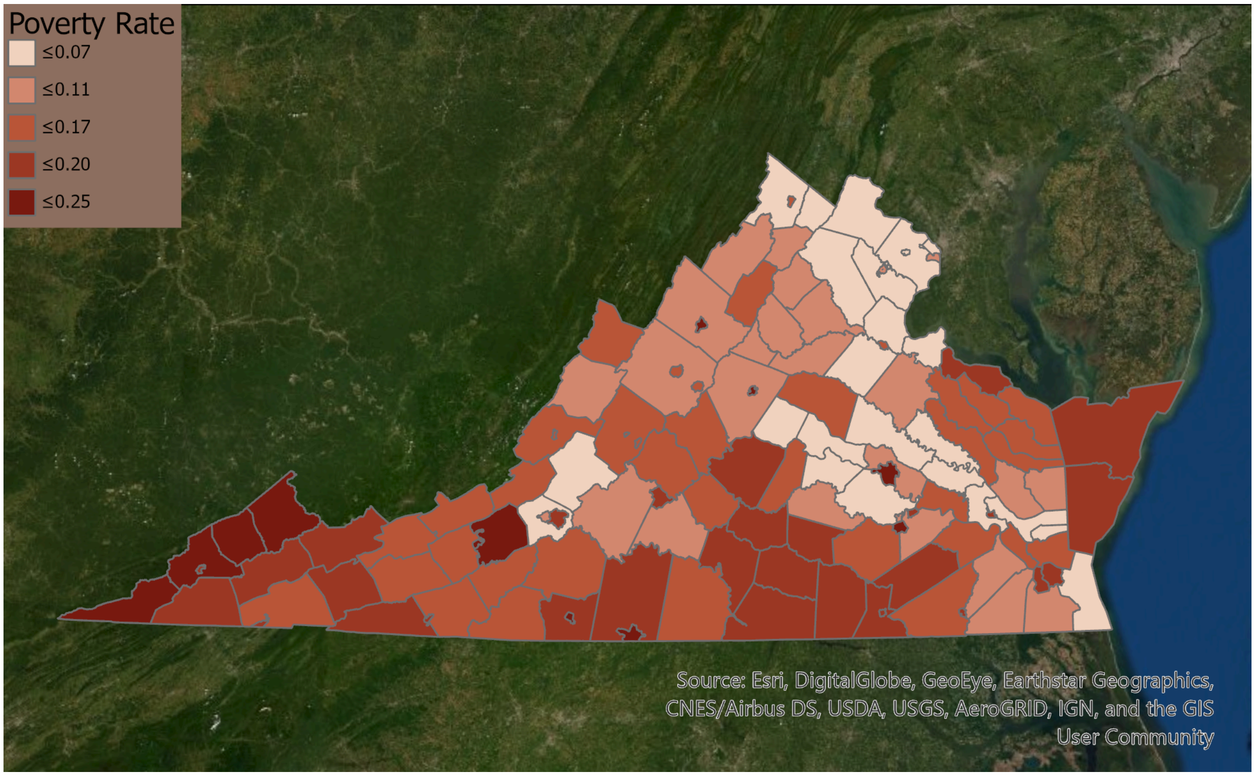

Fig 2: Poverty Rates in Virginia, normalized by quantity of households (2017).

The highest income found in Virginia are located primarily in the northern sections of the state (Fig 3) with lower incomes found in the west and south.

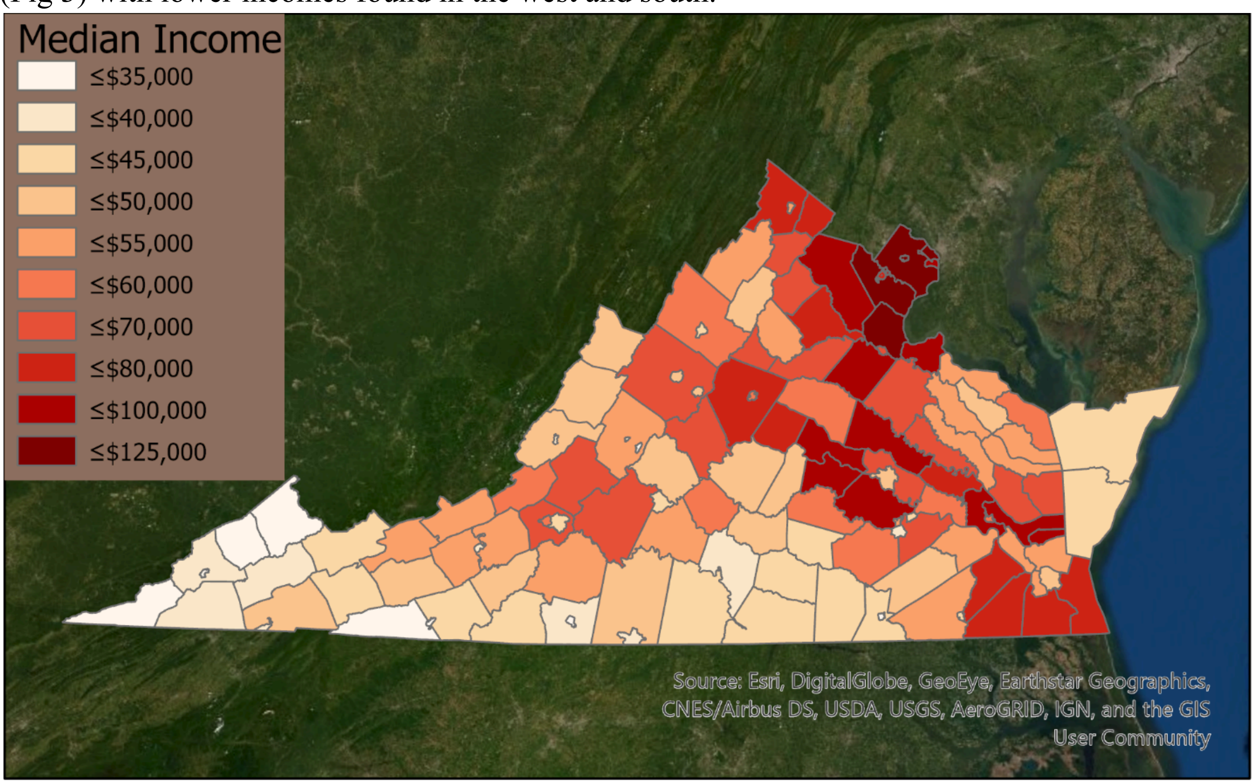

Fig 3: Median Income in Virginia (2017).

Energy Source

The heating energy sources are wood (Fig 4), liquid petroleum (Fig 5), oil/kerosene (Fig 6), gas from a utility (Fig 7), and electricity (Fig 8). The data is normalized by total households.

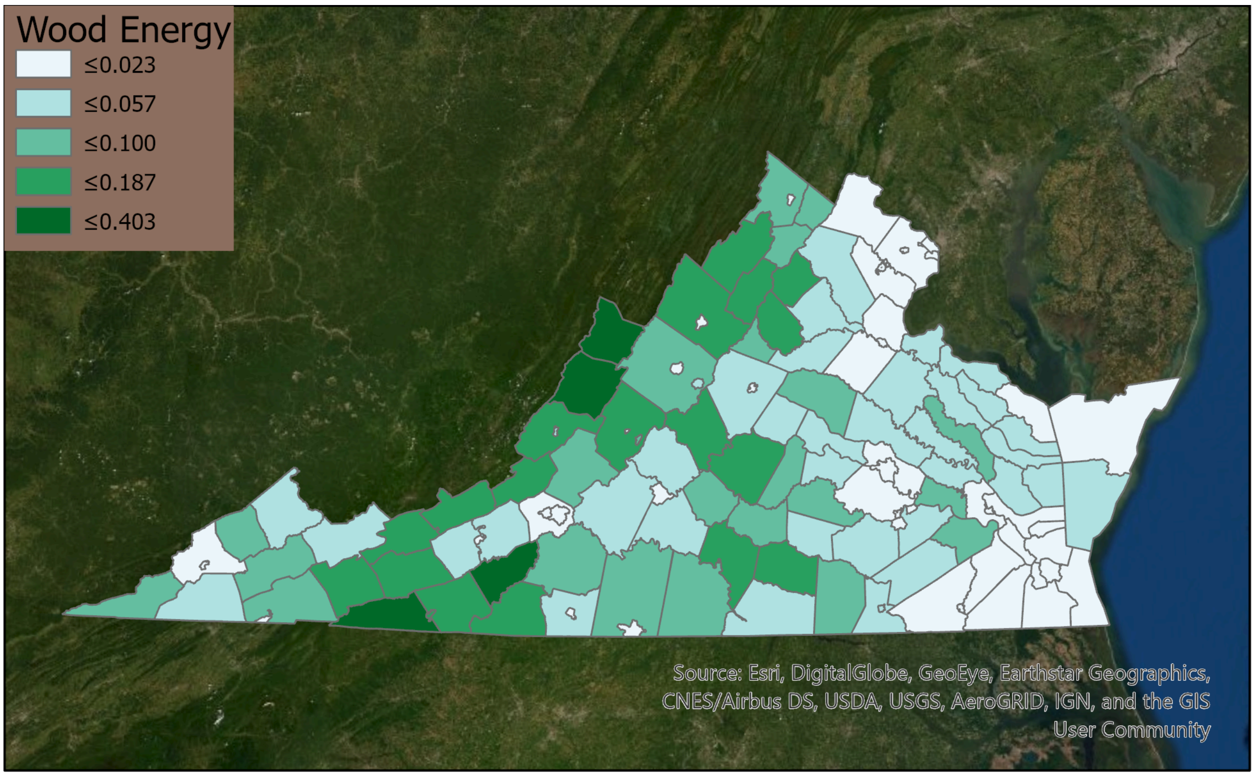

Fig 4: Wood Heating Source, normalized by total households (2017).

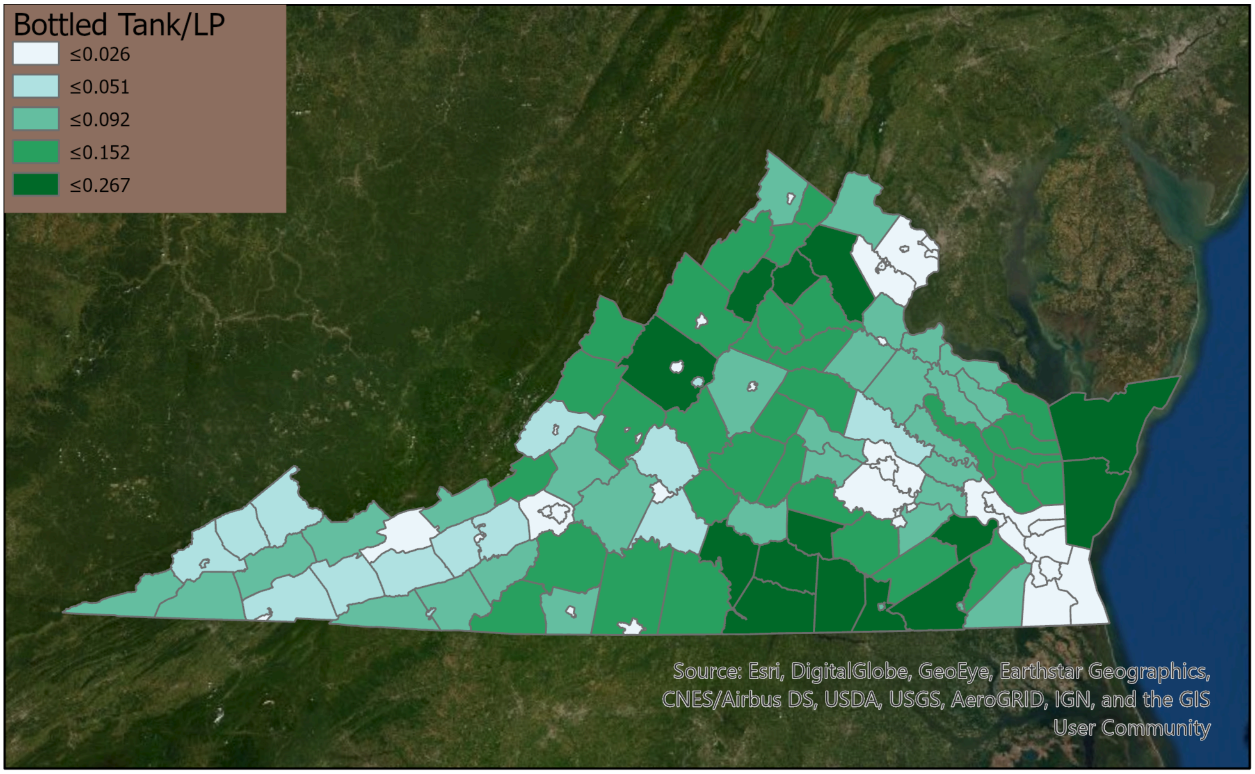

Fig 5: Liquid Petroleum Heating Source, normalized by total households (2017).

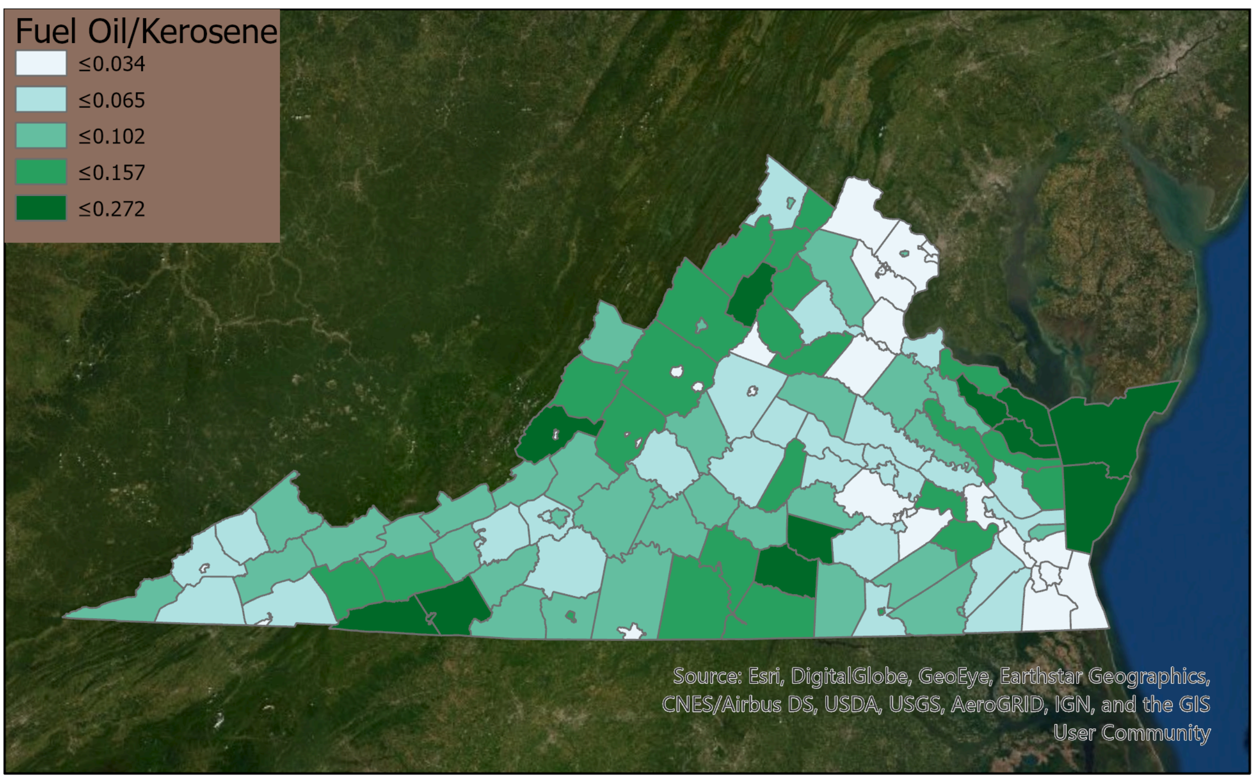

Fig 6: Fuel Oil/Kerosene Heating Source, normalized by total households (2017).

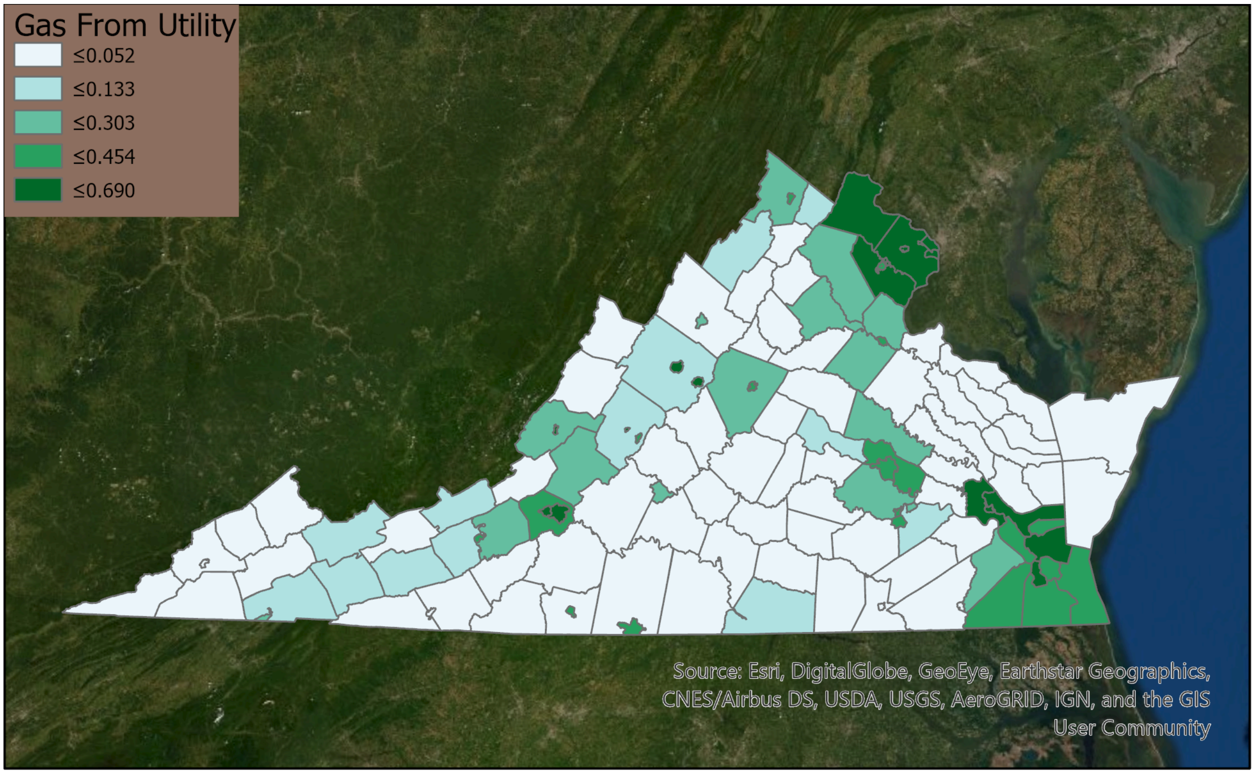

Fig 7: Gas From Utility Heating Source, normalized by total households (2017).

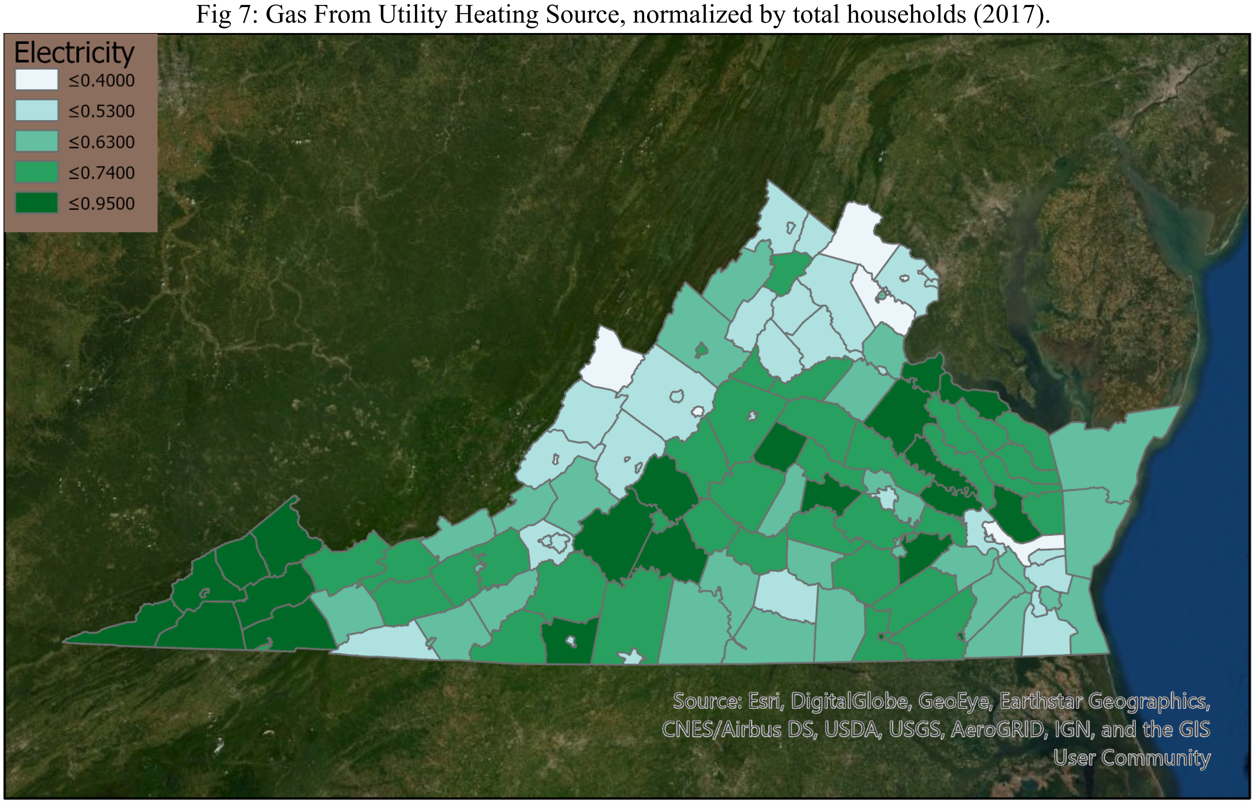

Fig 8: Electric Heating Source, normalized by total households (2017).

Wood heating is most prevalent in the western portion of the state, fuel oil is scattered spatially throughout the state, bottled tank/LP is most common in the eastern Tidewater and southern Piedmont region, gas provided by a utility is common in urban Virginia. Electric is by far the most common way to heat a home throughout the entire state.

Ordinary Least Squares (OLS)

The OLS regression was run with Number in Poverty as the dependent variable, with the energy types (Utility Gas, Bottled Tank/LP Gas, Electricity, Fuel Oil/Kerosene, and Wood) as the independent variables. The OLS results (Fig 9) show that a negative relationship exists between poverty and Bottled Tank/LP and wood heating sources. Whereas a more extreme positive relationship exists with the use of Fuel Oil/Kerosene heating. This means that households which use fuel oil/kerosene as a fuel source tend to have higher amounts of poverty.

Summary of OLS Results

Variable	Coefficient [a]	Probability [b]	Robust_Pr [b]	VIF [c]
Intercept	1583.915216	0.001143*	0.000075*	--------
UTILITYGAS	0.081915	0.014354*	0.072806	6.015742
BOTTLED_TANK_LP_GAS	-1.264838	0.001901*	0.000698*	2.402673
ELECTRICITY	0.231686	0.000000*	0.001948*	7.588728
FUEL_OIL_KEROSENE_ETC	3.561136	0.000000*	0.007182*	4.204219
WOOD	-2.130299	0.008042*	0.052553	2.252523

OLS Diagnostics

Multiple R-Squared [d]: 0.870637 Adjusted R-Squared [d]: 0.865544

Fig 9: OLS Regression.

GWR

```
----------- Model Diagnostics ------------
R2:                                 0.9210
AdjR2:                              0.9015
AICc:                            2534.7975
Sigma-Squared:                9205388.9878
Sigma-Squared MLE:            7397614.7240
Effective Degrees of Freedom:     106.8812
------------------------------------------
```

Fig 10: GWR Results.

Running a GWR on these variables yields a slightly better R^2 & Adjusted R^2 value over the OLS, from 0.86 to 0.90 slightly lower AICc score. The GWR allows a plotting of predicted values of poverty (Fig 11) given these explanatory variables.

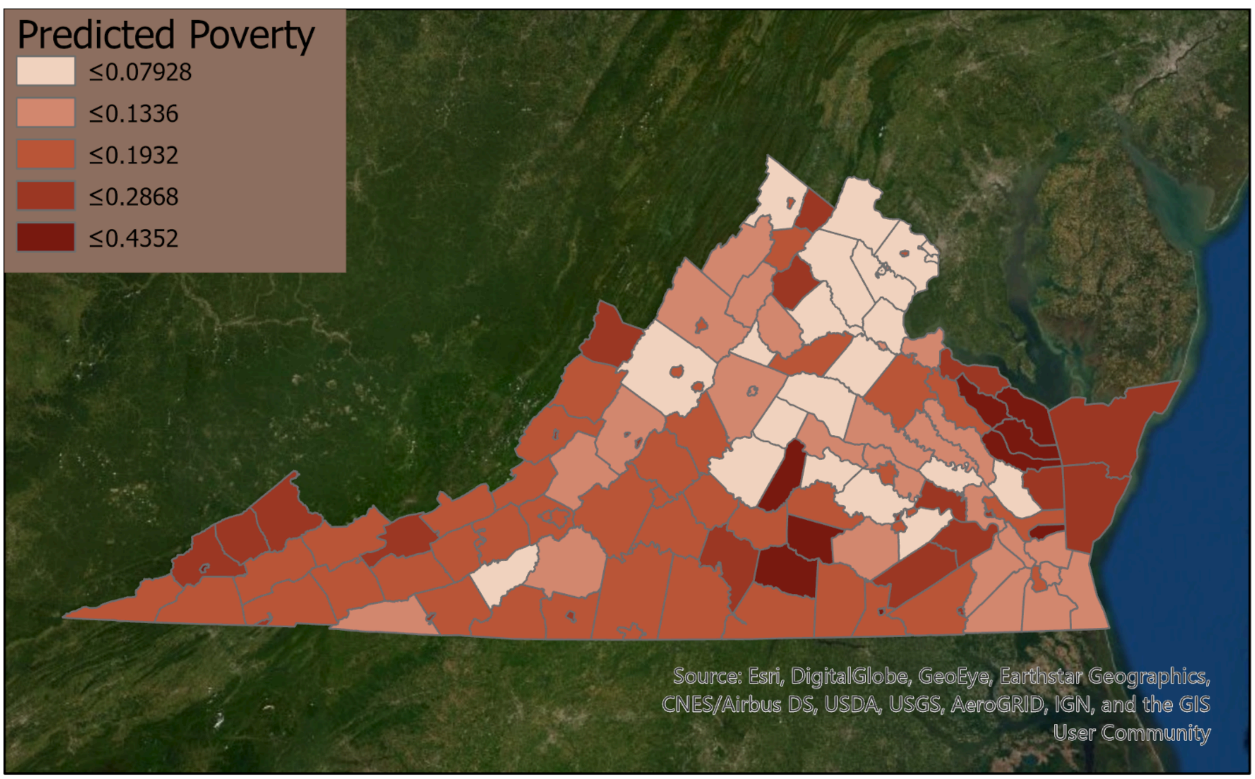

Fig 11: Predicted poverty values based on heating usage.

The predicted poverty rates are highest across the western part of the state toward the Piedmont and Tidewater region; the northern part of the state nearer to Washington DC has the lowest predicted rates. The model performance can be seen in Fig 12. The warmer red colors indicate areas where the predicted poverty rate is underestimated, whereas the colder, blue colors indicate overestimations. This is most notable in the Virginia tidewater.

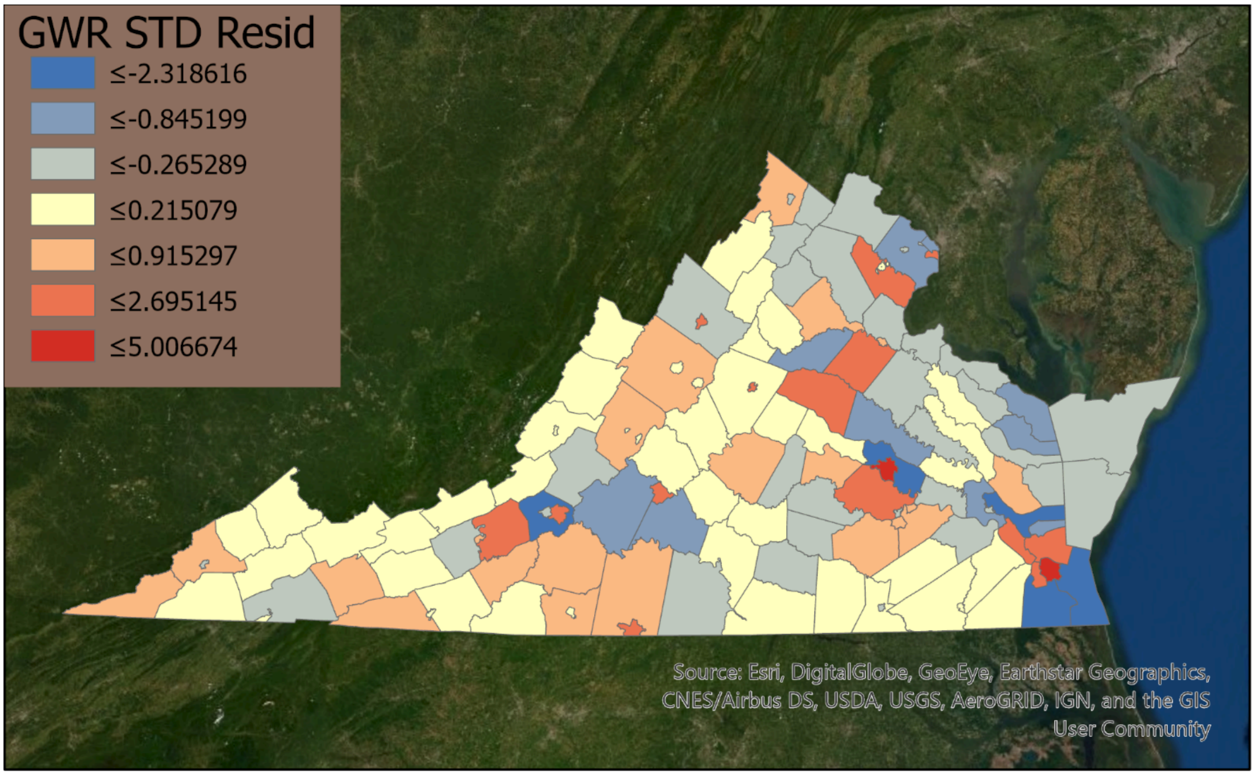

Fig 12: GWR Standard Residuals.

What This Means

The model's performance had an adjusted R^2 value of .90; this means that the model explains approximately 90% of the poverty rate itself – which is a statistically significant percentage. The standard residual map shows where discrepancies are observed between energy use and poverty rates. Using these regression models has shown that correlation exists between the type of energy used and the rate of poverty. It is strongest with Fuel Oil (Coefficient 3.561136) and Electricity (Coefficient 0.231686) vs. other heating sources. Median incomes in the northeastern portion of the state are highest whereas incomes go down as you go south and west in Virginia. Looking spatially at the state the main energy used in the northeastern corner is gas provided by a utility. Whereas the rest of the state has a combination of heating types. The most impoverished counties tend to have higher usage of Fuel Oil/Kerosene heating types – making up nearly a third of heating in counties across southern Virginia.

Discussion and Conclusions

The results from the regression models are not what was expected; originally, I anticipated wood heating and natural gas to be an indicator of poverty, as indicated in the by study by Pereira, Diogo Santos, et al. however, the OLS regression showed that in the state of Virginia there was not a significant correlation between natural gas and wood heating to poverty. This was a surprising result and was not anticipated. This certainly opens the door to more research and interpretation of the individual variables themselves.

The population densities certainly have an impact on the type of energy; the most densely populated areas of Virginia use utility gas, whereas rural areas use a combination of heating sources, but significantly less percentages use utility gas. As Virginia transitions into more renewable resources; seeing where the highest poverty rates exist will show where subsidies from the state and federal governments would be best applied. A different approach that I would have taken to my capstone would have been to utilize population densities and energy type. In addition, seeing how other demographics such as gender, age, and ethnicity correlate to energy use would be an area that would be intriguing and beneficial for those in government and nonprofits to know.

Works Cited

"American FactFinder." US Census, 5 Oct. 2010, factfinder.census.gov/.

Aslani, Alireza, and Kau-Fui V. Wong. "Analysis of Renewable Energy Development to Power Generation in the United States." *Renewable Energy*, vol. 63, Mar. 2014, pp. 153–161., doi:10.1016/j.renene.2013.08.047.

Bhattacharya, Mita, et al. "The Dynamic Impact of Renewable Energy and Institutions on Economic Output and CO 2 Emissions across Regions." *Renewable Energy*, vol. 111, Oct. 2017, pp. 157–167. *EBSCOhost*, doi:10.1016/j.renene.2017.03.102.

Bulut, Umit. "Testing Environmental Kuznets Curve for the USA under a Regime Shift: the Role of Renewable Energy." *Environmental Science and Pollution Research*, vol. 26, no. 14, May 2019, pp. 14562–14569., doi:10.1007/s11356-019-04835-6.

Daim, Tugrul, et al. "Forecasting Renewable Energy Production in the US." *Foresight*, vol. 14, no. 3, 2012, pp. 225–241., doi:10.1108/14636681211239764.

Dogan, Eyup, and Ilhan Ozturk. "The Influence of Renewable and Non-Renewable Energy Consumption and Real Income on CO2 Emissions in the USA: Evidence from Structural

Break Tests." *Environmental Science and Pollution Research*, vol. 24, no. 11, Apr. 2017, pp. 10846–10854., doi:10.1007/s11356-017-8786-y.

Goldfarb, Jillian L., et al. "Geographic Proximity to Coal Plants and U.S. Public Support for Extending the Production Tax Credit." *Energy Policy*, vol. 99, Dec. 2016, pp. 299–307., doi:10.1016/j.enpol.2016.03.029.

Greiner, Alfred, et al. "Economic Growth and the Transition from Non-Renewable to Renewable Energy." *Environment and Development Economics*, vol. 19, no. 4, Aug. 2014, pp. 417–439., doi:10.1017/s1355770x13000491.

Overview and Status Update of the §1603 Program. US Department of Treasury, 1 Apr. 2017, www.treasury.gov/initiatives/recovery/Documents/Status%20overview.pdf.

Pereira, Diogo Santos, et al. "Are Renewables Affecting Income Distribution and Increasing the Risk of Household Poverty?" *Energy*, vol. 170, 1 Mar. 2019, pp. 791–803. *EBSCOhost*, doi:10.1016/j.energy.2018.12.199.

Xu, Xiaojing, and Chien-fei Chen. "Energy Efficiency and Energy Justice for U.S. Low-Income Households: An Analysis of Multifaceted Challenges and Potential." *Energy Policy*, Elsevier, 5 Feb. 2019, www.sciencedirect.com/science/article/abs/pii/S0301421519300205?via%3Dihub.

Yarmosky, Alena. "Governor Ralph Northam Signs Executive Order to Expand Access to Renewable Energy, Support Clean Energy Jobs of the Future." *Virginia Governor* , State of Virginia, 17 Sept. 2019,

www.governor.virginia.gov/newsroom/all-releases/2019/september/headline-846745-en.h
tml.