Energy Distribution in North Carolina

https:
//github.com/meganlundequam/LundequamVanasse_EDA_FinalProject

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1 Rationale and Research Questions

Awareness of environmental injustice has been prevalent in North Carolina for decades. In fact, Warren County, a county just north of Durham, is widely recognized as the birthplace of today's environmental justice movement (O'Connell, 2016). In the late 1980s, the National Association for the Advancement of Colored People and others staged a protest against the state of North Carolina's decision to site a hazardous waste landfill in the predominantly colored county (Office of Legacy Management). Although the protests failed to prevent the siting of the disposal facility, the event shed light on environmental injustice trends with the EPA describing the movement in its 1994 Environmental Equity Draft as "the watershed event that led to the environmental equity movement of the 1980's" (O'Connell, 2016).

In North Carolina and across the US, a common expression of environmental injustice is the disproportionate biased siting of locally unwanted land uses sited next to low income and minority communities. An example of such a land use is energy production. The largest source of energy in the U.S. is fossil fuels and the burning of fossil fuels at power plants created emissions that can lead to respiratory and cardiovascular problems and increase the possibility of health issues ranging from cancer to immune system damage (Clean Air Markets). Minority, low-income, and indigenous populations frequently bear a disproportionate burden of these environmental harms and adverse health outcomes as a result of these siting trends (Clean Air Markets).

Due to a growing awareness of this trend and actions to combat environmental injustice across the U.S., it is necessary to examine the present day correlation of energy generators and minority, low income communities. This analysis explores the current (2020) distribution of utilities in relation to the distribution of low income communities to investigate to what extent this correlation still exists. This analysis further explores if that trend is true for different energy types. We were interested to see if there was any difference in the distribution of fossil fuel based utilities versus that of renewable energy sources in relation to minority and low income communities.

1.1 Research Questions:

This study examines the following key questions:

1.1.1 Question 1: Are energy production utilities in North Carolina located closer to low-income communities?

1.1.2 Question 2: Does the location of energy production utilities vary according to energy type? i.e., do different types of utilities have differing degrees of correlation with low income and minority communities?

2 Dataset Information

The data used for this analysis falls into two categories, energy related data and demographic data. We derived energy related data from the US Energy Information Association for the year 2020 (EIA-860 2020). The complete set of data files contains generator-level specific information for each year about existing and planned generators and associated environmental equipment at electric power plants with 1 megawatt or greater of combined nameplate capacity. The data sets utilized for this analysis include the plant-level data (2___Plant_Y2020.xlsx) and generator-level data (3_1_GeneratorY2020.xlsx) (where only data contained in the "operable" tab was analyzed). Geographic coordinates were obtained from the plant-level data set and combined with generator-level variables including Utility ID, Utility Name, Plant Code, Plant Name, State, County, Technology, Energy Source 1 (which represents the predominant energy that fuels the generator), and Nameplate Capacity (MW) (which represents the generator's maximum generation capacity in megawatts).

We derived demographic data from the US Census Bureau which we obtained through the tidycensus R package (API key = a8cad28557bae7c89aae6ea747549dd4816c6fbd) and specifically looked at the variables representing median household income, total population, the percent of the population with college degrees, the percent of the population at or below the poverty line, the percent of the population that is considered a 'minority' and the percent of the population that has received no schooling. For this analysis, we aggregated each of these variables by county.

3 Exploratory Analysis

In our exploratory analysis, we first examined the distribution of income levels across the state. Figure 1 shows there is a marked difference in median household income across counties in North Carolina.

Figure 2 shows the different types of generators across North Carolina, defined by fuel type. The counties are coded based on the median family income in that county. Note that there does appear to be some overlap between generator location and lower income counties, however a clear pattern is not discernible based on this visual alone. Energy generators are diverse in type and widespread throughout the state. Also of note is that generators powered by solar appear to be the most abundant, despite widespread knowledge that the predominant energy sources in the US are fossil fuels.

Figures 3 and 4 provide the context for interpreting the above figure. Figure 3 provides a breakdown of the number of individual generators based on fuel type, coded according to whether or not that fuel type is considered a renewable fuel, a fossil fuel, or other, for the state of North Carolina. While the renewable-fueled generators are far greater in number, Figure 4 shows that the majority of energy production comes from fossil fuel sources.

Figure 4 provides a visual representation of the aggregated energy production potential of the individual generators, using the nameplate capacity for each generator, again based on fuel type and coded according to renewable versus fossil fuel categorization. This shows that the largest contributor to energy production in North Carolina is natural gas, followed by coal.

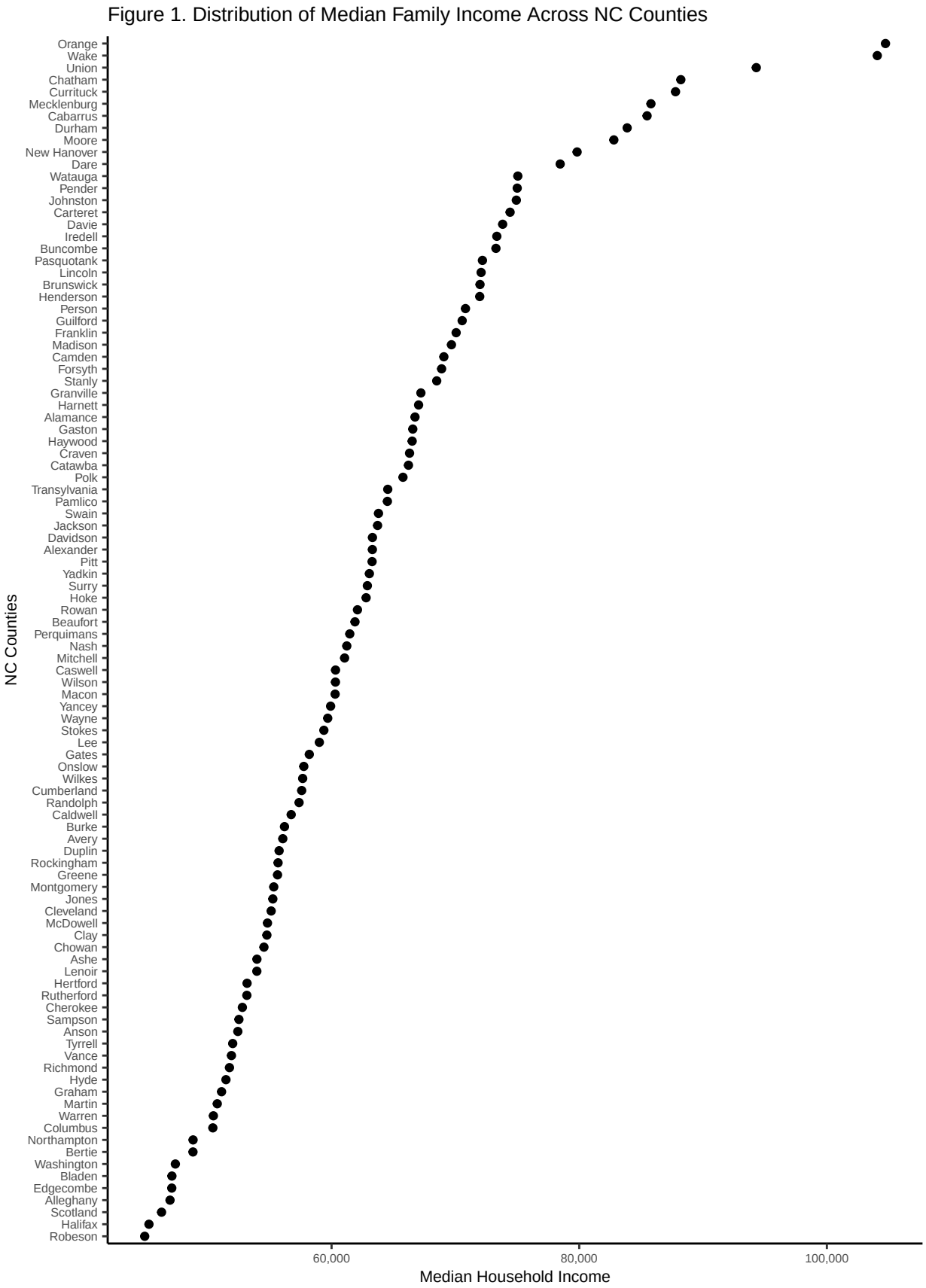


Figure 1: Median Household Income, NC

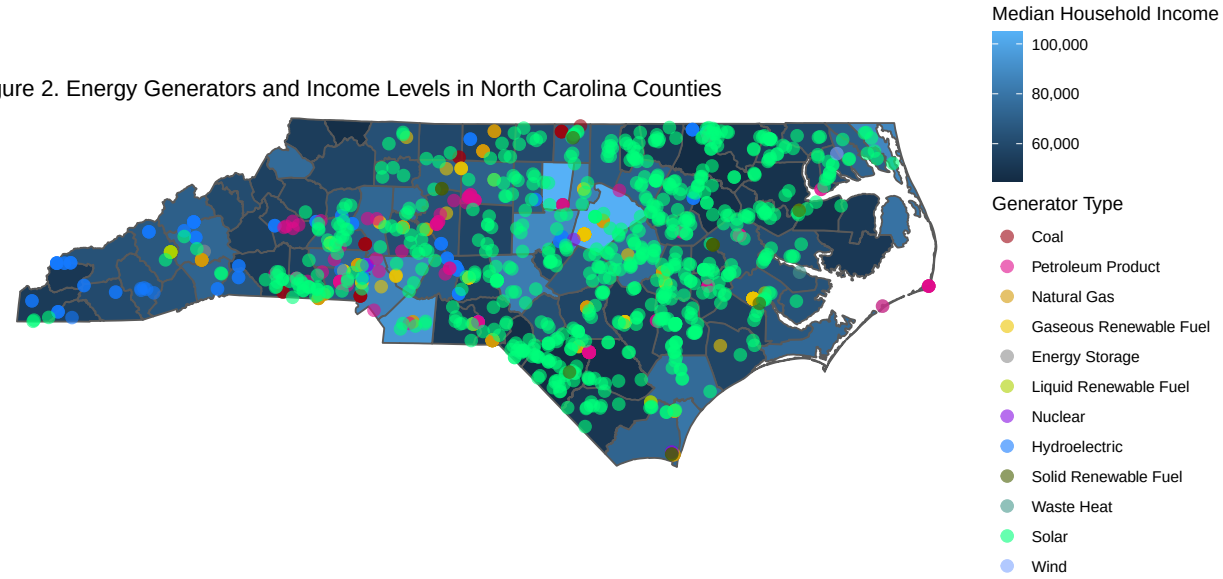


Figure 2: Energy Generation, NC

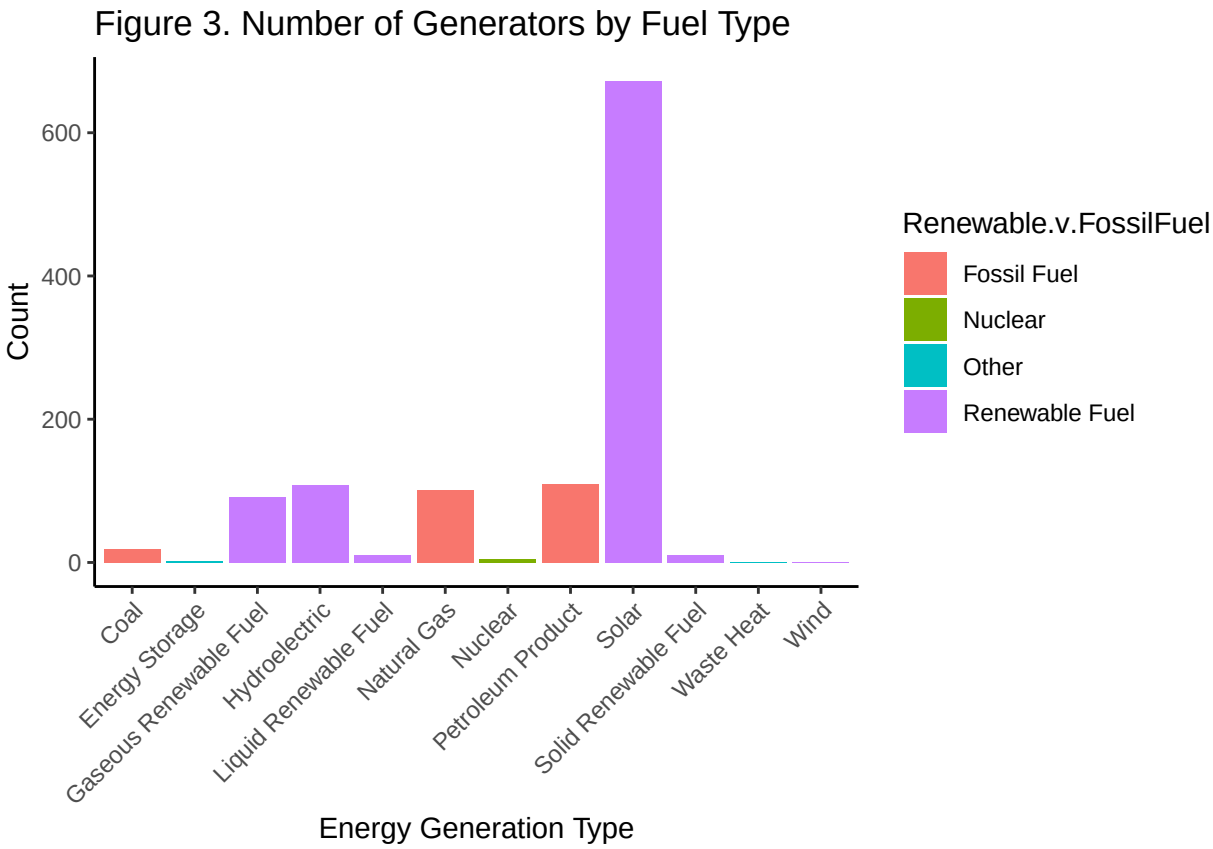


Figure 3: Generators by fuel type

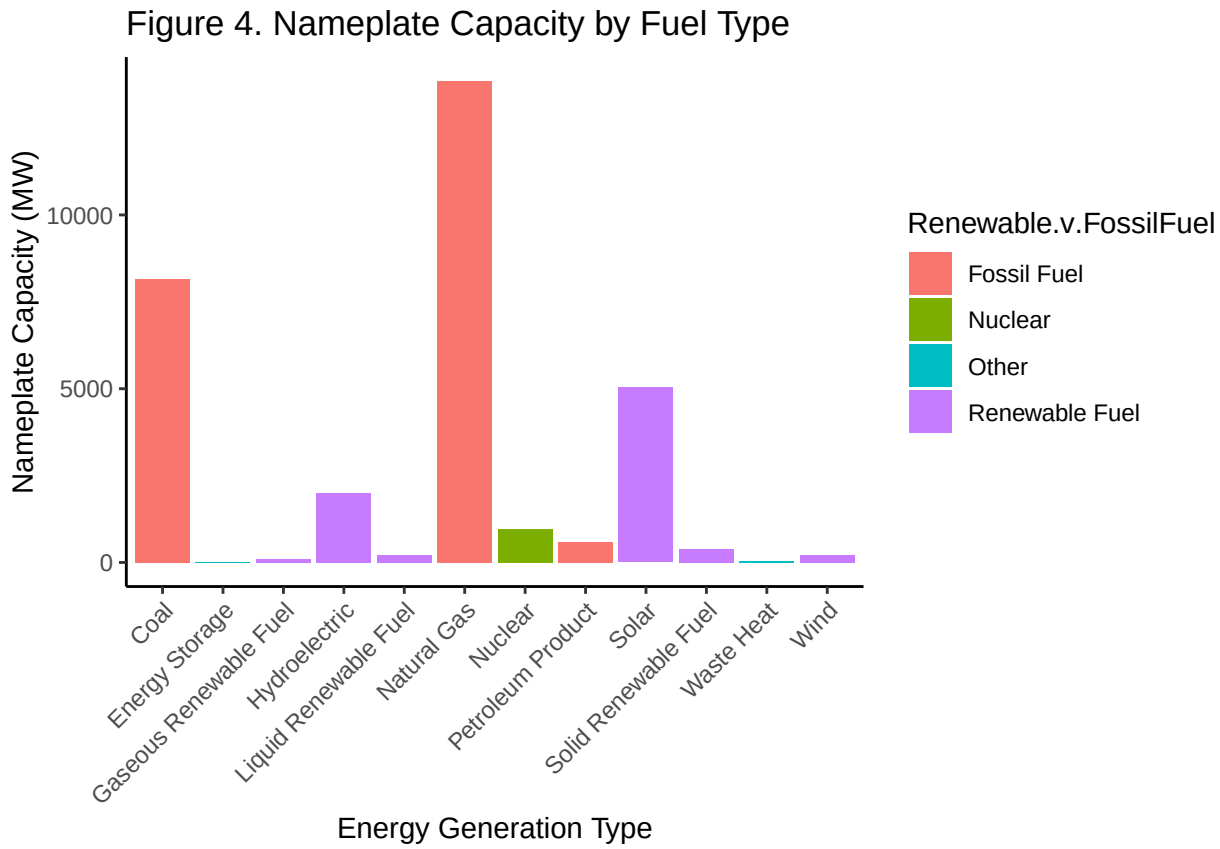


Figure 4: Nameplate capacity by fuel type

4 Analysis

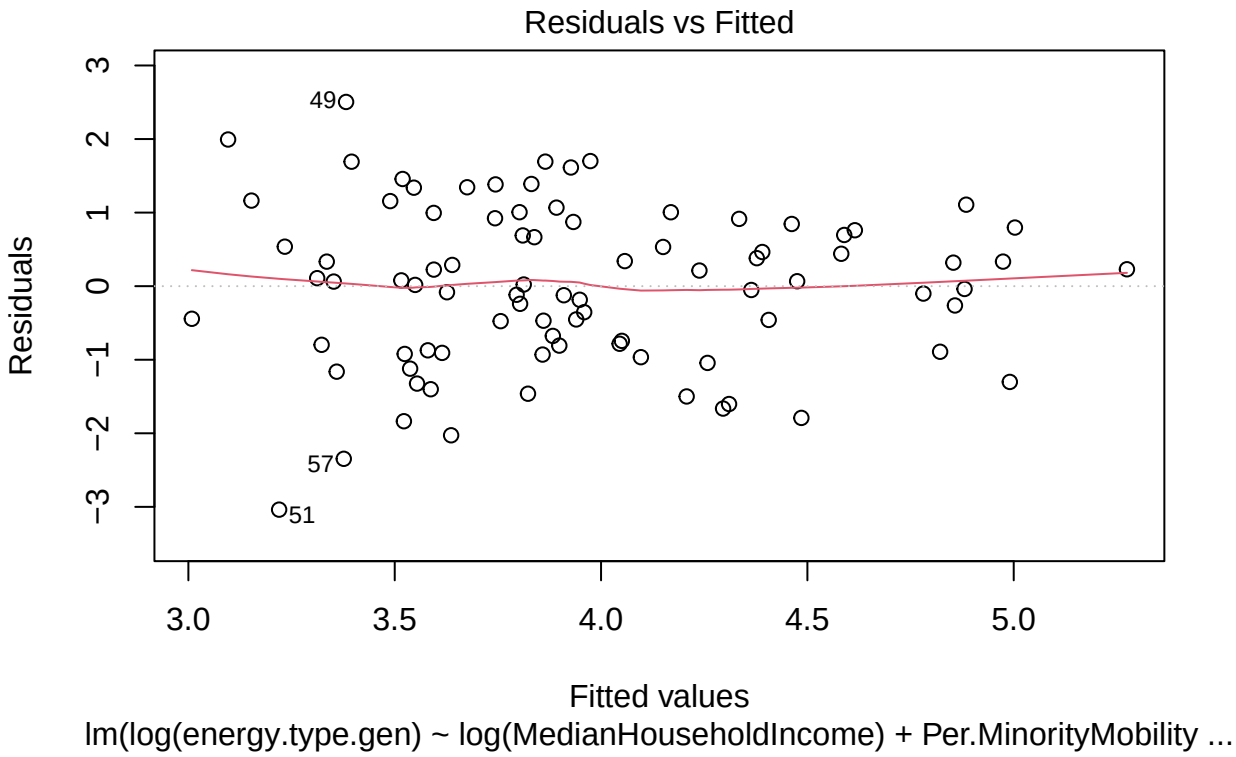
For this analysis we used the generation site's nameplate capacity as the independent variable demonstrating the size, and assumed impact, to a community. We aggregated these values into three broad categories: fossil fuel, renewable, and total energy generation in each county. We then combined this data with demographic data from the US Census Bureau for the year 2020. These dependent variables include the county's median income, the percent of the county's total population that have received a college or associates degree, and the mobility of the population based on race and poverty status.

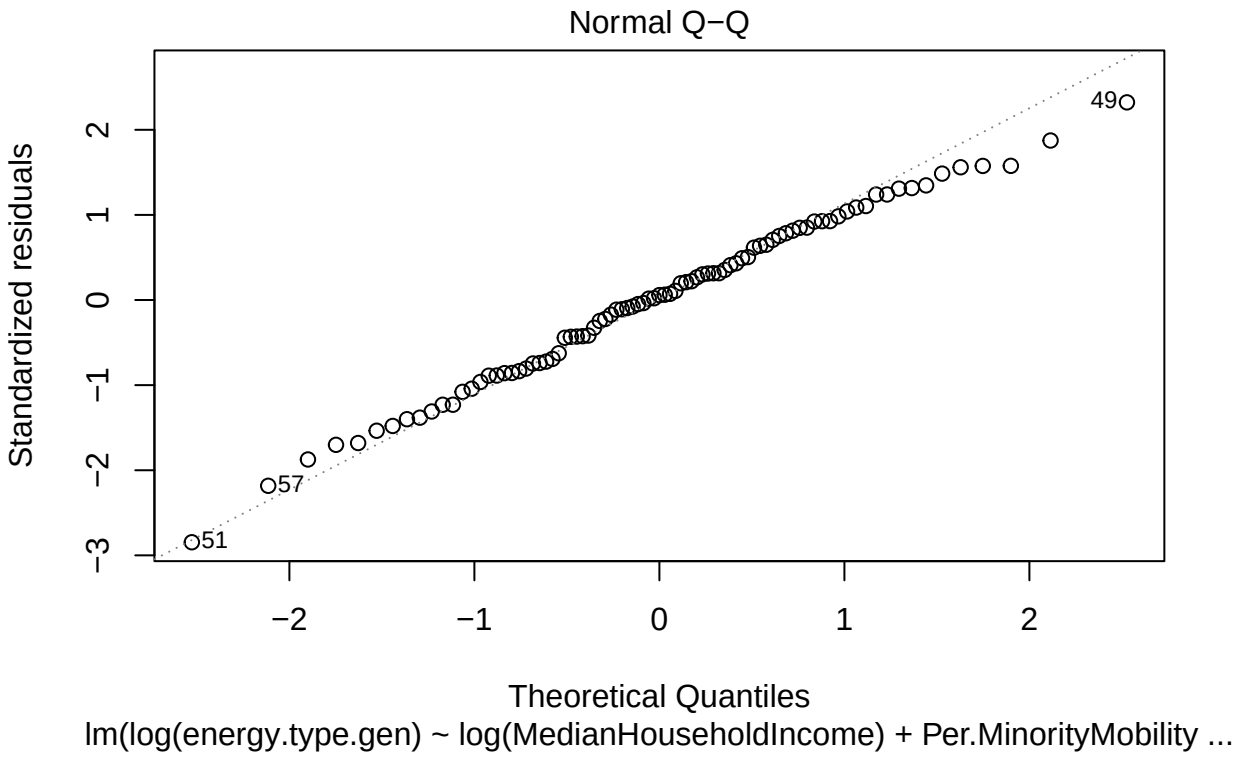
Given that both total energy generation within a county and their median income are positively skewed, we used log transformation on those variables. The remaining dependent variables were not log transformed as we already converted them to percentages of each county's total population.

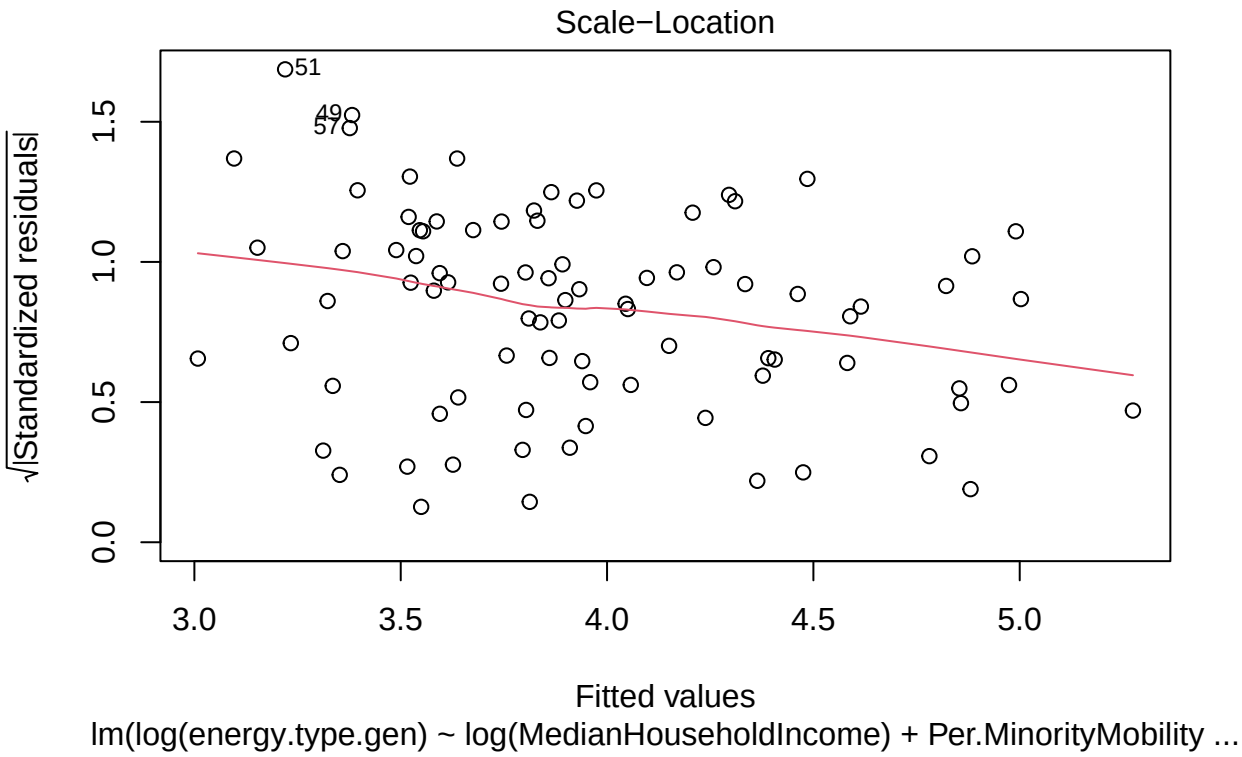
To help narrow the focus of our analysis we utilized Akaike's Information Criterion (AIC) to select our variables for each regression. This exploratory analysis demonstrated that, given our data limitations, focusing on renewable data and using our minority mobility and median income variables will offer the best analysis (AIC=21.31).

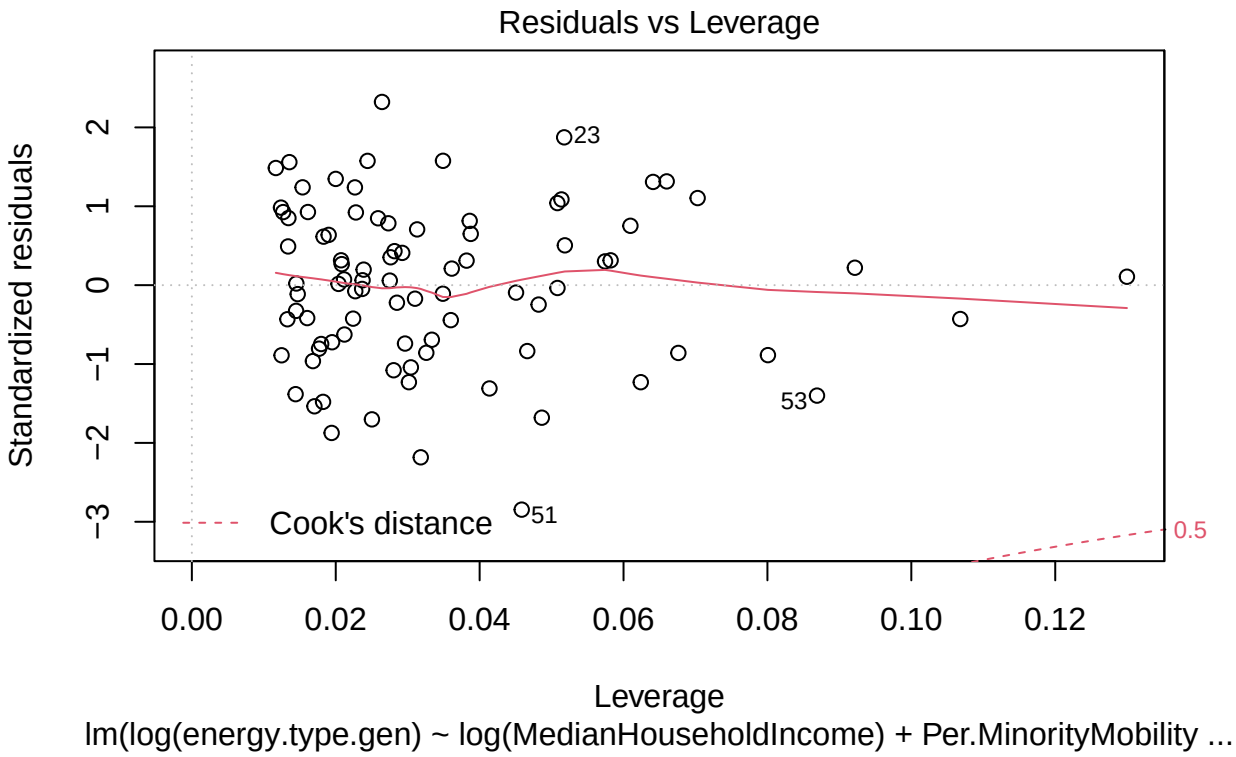
The regression analysis (Adj. R-squared = 0.1638) demonstrates with a 1% increase in a county's renewable energy infrastructure, the county's median income decreases by 1.51% (p-value = 0.0329) and the ratio of population that is a minority increases by 1.97% (p-value = 0.0117). This is in line with what we hypothesized, because although renewable energy is often thought of as a luxury resource, the infrastructure still undergoes NIMBY criticism by many wealthier individuals.

The figures below demonstrate the Residuals vs Fitted, Normal Q-Q, Scale-Location, and Residuals vs Leverage analysis of the renewable energy regression conveying the fit of the regression analysis.


Residuals vs Fitted
Residuals
Fitted values
lm(log(energy.type.gen) ~ log(MedianHouseholdIncome) + Per.MinorityMobility ...
49
57
51
3
2
1
0
−1
−2
−3
3.0
3.5
4.0
4.5
5.0


Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(log(energy.type.gen) ~ log(MedianHouseholdIncome) + Per.MinorityMobility ...
49
57
51
−3
−2
−1
0
1
2


Scale−Location
51
49
57
√|Standardized residuals|
0.0
0.5
1.0
1.5
3.0
3.5
4.0
4.5
5.0
Fitted values
lm(log(energy.type.gen) ~ log(MedianHouseholdIncome) + Per.MinorityMobility ...


Residuals vs Leverage
Standardized residuals
2
1
0
−1
−2
−3
23
53
51
Cook's distance
0.5
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Leverage
lm(log(energy.type.gen) ~ log(MedianHouseholdIncome) + Per.MinorityMobility ...

5 Summary and Conclusions

5.1 Summary

In summary, we evaluated the current state of energy generation-related environmental injustices by investigating the distribution of energy generators in North Carolina. We found that spatial distributions of energy generators at the county level showed little correlation with county-wide demographics. The only correlation significance was found to be among the spatial distribution of only renewable energy generators and the demographic variables, median income and the percent minority. This is likely due to the fact that there are a greater number of renewable energy sources than fossil fuel sources and correlation cannot be traced at the county level. Additionally, given that such a small number of generators are responsible for providing such a large percentage of the energy needs of the state, a country-wide analysis of energy generators in relation to low income, minority communities might return more significant correlations. Despite this, it is still significant to note that the siting of these renewable energy generators is correlated with low income, colored communities as this suggests that even though there is growing awareness around environmental justice, newer energy sources, albeit renewable, are still being sited near these historically under-served communities. This shows that we could be on a path to reproducing the same distributional impacts of energy generation even though we are transitioning to cleaner energy.

5.2 Conclusion

Energy generators have historically and continue to be disproportionately located next to low income, colored, and under-served communities. We suggest further assessment of the health and social implications of siting clean energy generators near under-served communities. Additionally, a more granular analysis of the communities immediately surrounding specific plants could reveal correlations not captured in this county-wide analysis. Further investigation into these correlations and research around the current siting policies for new energy generators could shed light on opportunities to prevent the exacerbation of environmental injustices as our nation's energy portfolio evolves to embrace renewables.

6 References

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