# Residential Solar in North Carolina: Supporting Clean Energy and Environmental Justice Communities

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**Understanding the Problem**

Renewable energy implementation is an essential step in decarbonizing the US electricity sector and achieving net-zero goals by 2050. Residential solar installations support the clean energy transition and can help alleviate the financial burden of energy costs, which impose a regressive cost structure across communities [1]. According to data from the state of California, installing residential solar costs an average of $27,000 typically consisting of a $7,000 fixed cost plus an additional $3,000 per kilowatt (kW) [2]. Although some existing programs provide financial support to promote residential solar installations, for example a 30% tax credit, homeowners are still responsible for most of the cost [1]. Even with the tax credit low-income individuals may not have the capital to pay for solar, which results in this type of assistance primarily supporting middle- and high-income individuals with the ability to pay [1]. In an effort to mitigate these inequities, policies to encourage residential solar should implement eligibility criteria that prioritize solar installations in low-income and marginalized communities.

The Clean Energy Futures policy analysis project estimates that North Carolina will need to implement 100.2 gigawatts (GW) of new solar capacity to reach net-zero emissions by 2050 with allowances for banking and partial crediting for natural gas [3]. North Carolina is a particularly apt case study for this research because the state will need to install the second largest volume of solar capacity in the US after Florida [3]. This research brief examines potential solar power generation in North Carolina with a focus on solar installations in environmental justice communities in an effort to address the clean energy transition and energy justice across the state.

The US Environmental Protection Agency (EPA) defines environmental justice as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies” [4]. In May 2021, the White House Environmental Justice Advisory Council published a report that provided recommendations to the federal government regarding how to address and mitigate environmental injustices [5]. The Council included policy and environmental experts, community stakeholders, scientists, and more. The report specifically recommended installing discounted rooftop solar for low-income residences to mitigate disproportionate energy costs [5].

For this analysis I looked at demographic indicators that may be prevalent in environmental justice communities, including income level and race, using data from the US Census Bureau’s 2019 American Community Survey (ACS). I discuss in detail the parameters I used to define potential environmental justice communities in the Methods section of this brief.

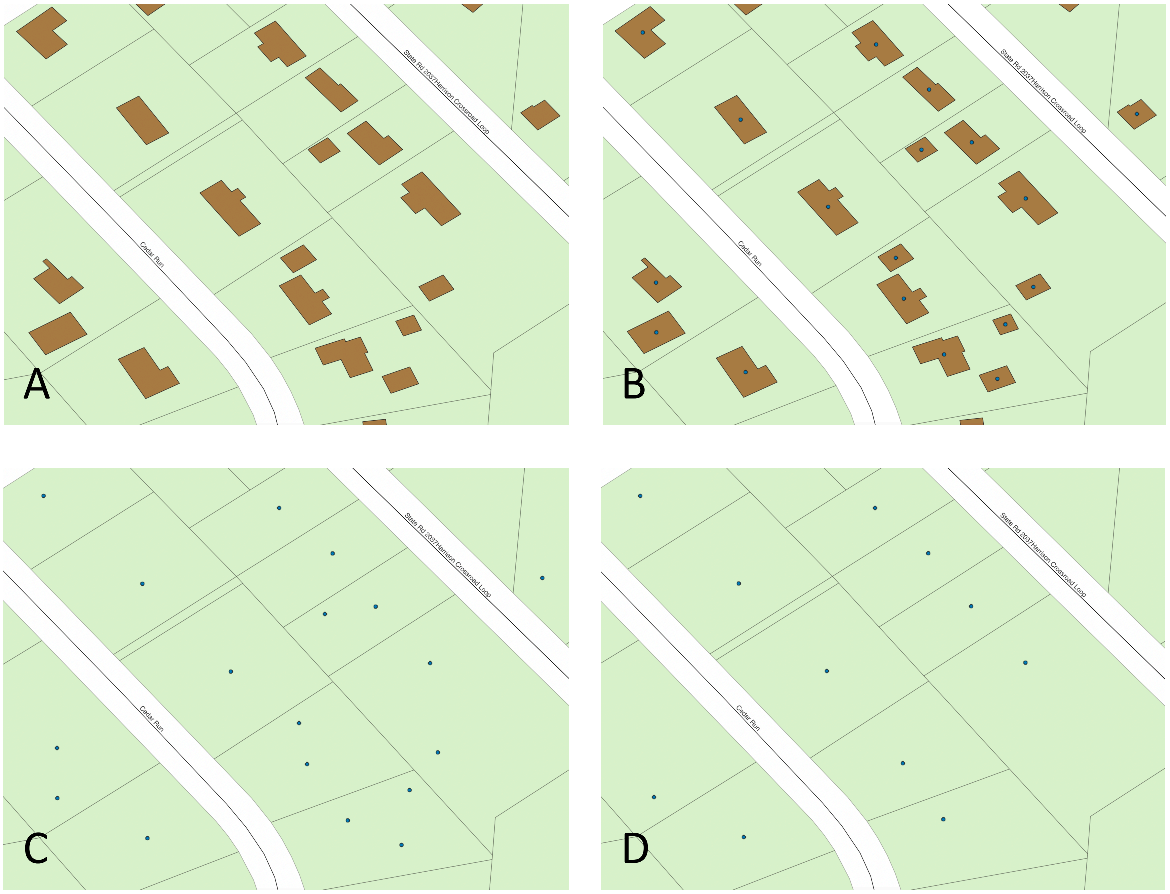


**Figure 1. Progression of geospatial analysis and filtering.** (A) Parcel-level data and corresponding building footprints spatially joined. (B) Centroid identified for each building footprint. (C) Building footprint polygons removed and building footprint centroids are assigned to the parcels in which they are spatially located. (D) Building footprint centroids filtered to only keep the building footprint with the largest area in each parcel.

This study produced a data analysis tool that conducts county-level analyses and can be scaled to understand the potential residential solar capacity for the state of North Carolina. For the purposes of this brief, I describe a case study analysis for Rockingham County. I selected Rockingham as a case study because it represents close to the average population density, income level, and race distribution for the state of North Carolina. Additionally, Rockingham is a suburb of Greensboro and is therefore not completely rural or urban.

**Methods**

**Geospatial Data Configurations.** This research examines the geospatial relationship of buildings, parcels, and Census blocks and block groups by county in North Carolina. Figure 1 outlines a high-level overview of the first step of geographic filtering conducted in this analysis. Using geographic markers, I spatially joined building footprints to their corresponding parcel. I used North Carolina building footprint data from Microsoft's open access repository of US building footprints [6] and parcel data from North Carolina's centralized open access data sharing resource [7].

After spatially joining the building footprints to their corresponding parcel I filtered the footprints to only keep the largest building on each parcel. Multiple buildings on one parcel may typically include the main residence and a shed, detached garage, etc. For the purposes of this analysis, I assumed the largest building footprint on the parcel to be the main residence and would therefore be the most suitable structure on which to install solar for residential energy use.

Once each parcel had only one building footprint associated with it, I spatially joined the parcels and Census-defined blocks. I then calculated total building footprint area and corresponding solar capacity at the block level before aggregating the blocks to the block group level.

**Solar Capacity.** Solar panels are typically not installed across the entirety of a roof's surface area. Solar arrays are typically placed on the south facing part of a roof to ensure the maximum level of daily sun exposure. According to residential solar installation data for the state of California, a residential home typically has a 6 kW array with an interquartile range (IQR) of 4 to 8 kW [2]. For the Rockingham County pilot study a 25% surface area estimate yielded an average array size of 6.88 kW with an IQR of 5.23 to 9.11 kW. To arrive at these estimates, I multiplied the usable roof area by the number of 4 kW panels that could fit in the area given that each 4 kW panel requires 25m$^2$ of roof area for installation [8]. For these reasons I determined that 25% of the roof area would be a reasonable estimate of the usable section of a roof for solar installation. Figure 2 provides a representation of the estimated roof area on which the solar panels would be installed.

Due to building structural integrity and historical district restrictions I assumed that any buildings built prior to 1950 would not be fit for solar installation. However, the Microsoft building footprint data did not provide the age of each building. Instead, I used Census ACS data at the block group level to approximate the proportion of buildings in each block group built during or after 1950. I then applied the estimated percent of viable buildings to the total building footprint area to estimate the total roof area viable for solar installation in each block group.

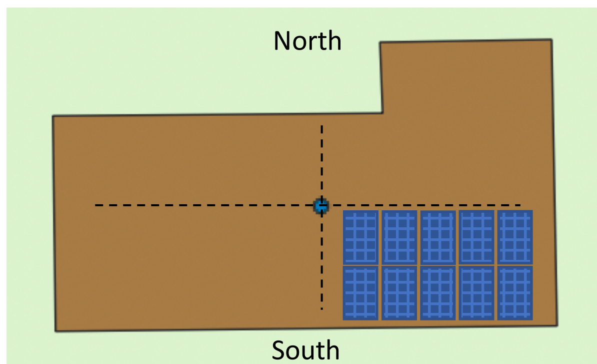


**Figure 2. Rooftop solar capacity estimation model.** The model estimates 25% of the total roof area to be fit for solar installation. Arrays should be installed on the south facing side of roofs to ensure maximum daily sun exposure.

**Census Variable Analysis.** The Census ACS provides limited data at the block level but additional detailed data at the block group level. For this reason, I aggregated blocks to the block group level to analyze population demographics and house characteristics. For this analysis, I analyzed block group data on race, median household income in the last 12 months, and building construction year.

The building construction year was used in the solar capacity estimation previously described in this brief. I used race and income data to estimate the locations of potential environmental justice communities.

**Environmental Justice Communities.** Since there is currently no federal definition for the parameters that define an environmental justice community, I analyzed block groups by race and median household income. I defined environmental justice communities as those in which residents were predominantly people of color, low income, or both. I first analyzed all block groups in North Carolina to determine the bottom quintile for median income ($36,000) and the top quintile for percent of people of color (55%) in all block groups statewide. I defined a block group as predominantly people of color if people of color accounted for more than 55% of the block group population. I defined a block group as low income if the median household income in the past 12 months was less than $36,000.

**Results**

Figure 3 depicts the main findings from this analysis. The heat map shows the estimated kW capacity by block group for Rockingham County. The map identifies potential environmental justice communities with “R”, “E”, and “RE” labels. The “R” label refers to race demographics and identifies block groups in which more than 55% of residents are people of color. The “E” label refers to economic demographics and identifies block groups in which the median income in the

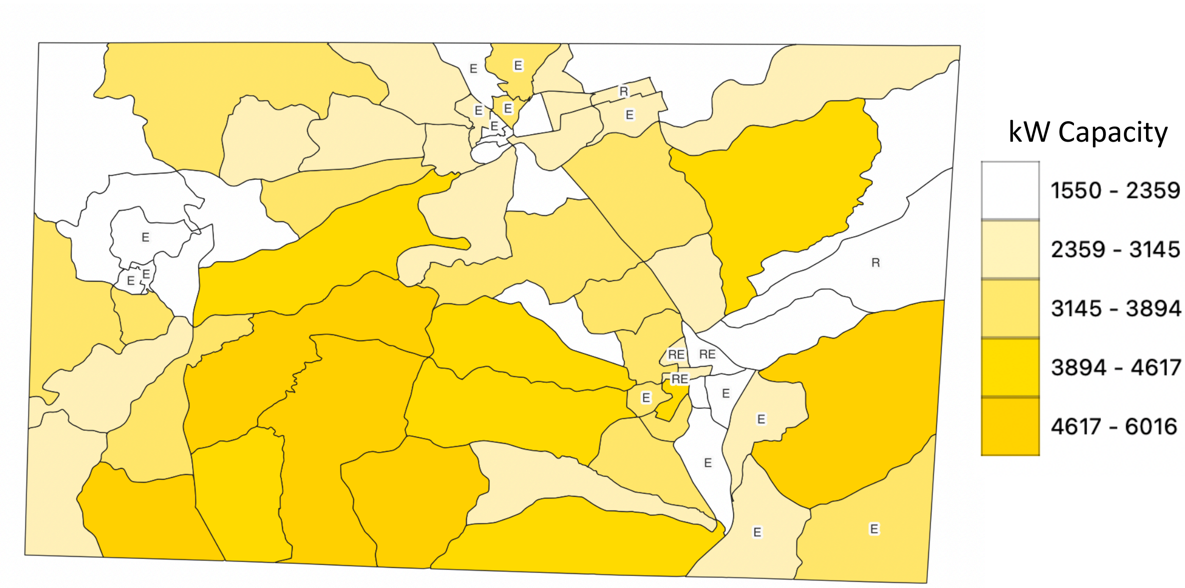


**Figure 3. Residential solar kW capacity by block group, Rockingham County.** Census block groups are heat mapped according to the potential residential solar capacity (kW) estimated by the model. The “R” labels denote block groups in which the proportion of people of color residing in the block group is over the 80th percentile (55%) for the state. The “E” labels denote block groups in which the median income level for the past 12 months is below the 20th percentile ($36,000) for the state. The “RE” labels denote block groups in which the proportion of people of color residing in the block group is over 55% and median income is less than $36,000.

past 12 months is below $36,000. The “RE” label identifies block groups that meet both the race and economic criteria. The model predicts that Rockingham County can install approximately 211 megawatts (MW) of residential solar including an estimated 50 MW in environmental justice communities and 161 MW in non-environmental justice communities.

To further analyze the distribution of solar by block group I calculated the proportion of solar in potential environmental justice communities and non-environmental justice communities. Overall, 76.1% of kW capacity is in non-environmental justice communities, 18% is in block groups where median income is less than $36,000, 2.5% is in block groups where more than 55% of the residents are people of color, and 3.4% is in block groups where the median income is less than $36,000 and more than 55% of the residents are people are color. Additionally, I looked into the population distribution. For Rockingham County, 72% of the population does not live in an environmental justice community, 21% live in block groups where the median income is less than $36,000, 3% live in block groups where more than 55% of the residents are people of color, and 4% live in block groups where the median income is less than $36,000 and more than 55% of the residents are people of color.

**Discussion**

To promote the installation of residential solar and mitigate environmental injustice, policymakers and solar program directors must understand the demographics of residents in North Carolina and focus communication, outreach, and funding in block groups that may be environmental justice communities. The map in Figure 3 shows that environmental justice communities may be clustered and may not be where the highest volume of solar is likely to be installed. For non-environmental justice communities, the proportion of kW capacity is larger than the population proportion, which suggests that residents in non-environmental justice communities live in larger houses. Additionally, the relatively low proportion of the population (4%) living in communities where the median income is less than $36,000 and more than 55% of residents are people of color may mean that these communities are often not prioritized by solar installation initiatives.

**Conclusion and Next Steps**

This tool provides North Carolina policymakers and stakeholders with a resource to identify potential environmental justice communities at the block group level and estimate the capacity of residential solar that can be installed in each community. While the results presented here are specific to Rockingham County the tool has the ability to perform this analysis on all 100 counties in North Carolina.

Moving forward I plan to conduct this analysis for all counties in North Carolina to create a resource that estimates potential solar generation at the state level and specifically solar potential within environmental justice communities. Policymakers and solar industry stakeholders can use this information to support the clean energy transition and prioritize solar installations in environmental justice communities.

**References**


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