EXAMINING THE SUSTAINABILITY OF SUSTAINABILITY: THE RELATIONSHIP BETWEEN RESIDENTIAL SOLAR ENERGY & GENTRIFICATION IN SAN DIEGO, CA

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ABSTRACT

Jessie LaMasse: Examining the Sustainability of Sustainability: The Relationship between Residential Solar Energy & Gentrification in San Diego, CA

(Under the direction of Mr. Jeffrey Mittelstadt)

Minimal research examines the social impact of residential solar energy on communities. This thesis provides a first look at the wholistic sustainability of renewable energy by examining the relationship between solar energy growth in both owner-occupied and renter-occupied households and the probability of gentrification occurring in San Diego, CA. The research aims to help policymakers, solar businesses, and nonprofits make educated decisions about solar energy deployment. The regressions indicated that residential solar energy growth in owner-occupied households and gentrification occurring between 2000-2018 are not statistically significant. However, residential solar energy growth in renter-occupied households and gentrification occurring between 2000-2018 are statistically significant under some conditions. The qualitative interviews also found renters faced greater barriers to residential solar energy. Thus, solar energy growth in renter-occupied households creates an area of concern. Further research should use a diversity of cities and conditions to examine the relationship between residential solar energy and gentrification pressures.

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INTRODUCTION

Overview

While sustainability is becoming increasingly popular in business, its progress could create deeper inequalities if the growth is not inclusive. Sustainable capitalism is an economic system in which business and capital seek to maximize long-term value through environmental, social, and governance metrics (The Generation Foundation, 2017). In August 2019, the Business Roundtable declared the purpose of a corporation to serve all stakeholders "by embracing sustainable practices across our businesses". Stakeholder-centered sustainability not only benefits shareholders in the company but also customers, employees, communities, and the environment alike (2019). As a result of the statement, major companies, such as IBM, Amazon, and Microsoft, made commitments to be net-zero carbon across their businesses by 2040 (The Climate Pledge, n.d.). However, despite the increasing commitment to sustainability and net-zero emissions, the 2019 UN Sustainable Development Goals Report shows that the United States remains stagnant on reducing inequality, with major challenges remaining (Sachs et al., 2019).

The Generation Foundation details that social and environmental causes are interconnected--one cannot be solved without considering the other in equal measure. The foundation suggests, "although the environmental imperative to decarbonize the economy is profound and urgent, progress will be significantly compromised if the case for change is not grounded in inclusive growth" (2017, p. 6). In other words, sustainable growth is dependent on inclusive growth. Inclusive growth allows the benefits of business and capital to be shared more widely, avoiding inequality growing too high and harming capitalism's own sustainability (The Generation Foundation, 2017).

My interest in the interconnection between social and environmental sustainability drove my curiosity about the relationship between environmental improvement projects and displacement pressures, or gentrification. At first glance, environmental improvement projects seem positive for sustainability from both environmental and social elements. For most, the projects hope to decrease emissions and improve the quality of life for the local community. However, prior research suggests that indirect neighborhood effects can regress the project's total impact. Rigolon and Nemeth (2020) studied park development projects in urban settings to find that large parks or those located closer to downtowns increased housing prices and displaced low-income people of color in historically disinvested neighborhoods. With greater attention to the offset effects of park development, both environmental and social improvements could improve the long-term sustainability and resilience of communities; however, the isolation of these two issues created deeper inequality for the historically disadvantaged neighborhoods.

A popular sustainability strategy thus far is renewable energy. Many businesses, policymakers, and homeowners switched energy sources quickly because of the underlying financial benefits alongside the reduced environmental impact. However, as companies continue to focus on net-zero carbon commitments, I began to question the offset effect of renewable energy. Could the new technology further displace groups who already faced historical inequality? If the growth is not inclusive, would those left off the grid face worse conditions? A study from McKinsey in 2018 indicated that 1.6 trillion dollars of renewable power investments are expected to enter the stock market by 2030 (Donovan et al., 2020). When the U.S. Energy Information Administration expects solar to be the leading source of renewable energy by 2050, what impact will this have on historically displaced communities? (Linga, 2020). The deployment of solar energy into neighborhoods brings many benefits, including new jobs, lower utility rates, and decreased emissions; however, no research exists on the impact of residential solar energy on neighborhood displacement. With the rapid growth of solar energy, the industry's speed and size creates an area of concern. To my knowledge, the only research on the indirect impact of residential solar energy is regarding direct housing price premiums and utility rate effects (Brinkley and Leach, 2019; Cai et al., 2013). Thus, my research question takes a first look into the relationship between high solar growth and gentrification.

Motivation and Roadmap

While the idea of sustainable investing aims to hold corporations accountable for financial returns with environmentally and socially conscious practices, historic practices in investing have not had the same goal. Traditional investment strategies mostly focus on generating wealth for shareholders. Thus, the transition to sustainable investing needs guidance and supervision to realize the positive societal impact along with the financial returns. While measurements for social and environmental factors exist, the accountability of company transparency is still a barrier. Without an intentional tracking of intangible factors, the investment strategy could become a façade for contemporary investing that continues to focus on short-term wealth for shareholders. For instance, the term 'greenwashing,' or misleading information on a company or products' environmental concerns, allows companies to gain positive public relations from environmentally friendly branding while continuing harmful business practices. As the trend for sustainable investing continues to grow, I found it imperative to examine the bottom line of recent investment trends that denote sustainability.

One leading sustainability strategy is the investment in renewable energy. The U.S Energy Information Administration (EIA) expects renewables to surpass nuclear and coal by 2021, with solar as the leading source of renewable fuel by 2050 (Linga, 2020). I see this energy revolution as potential to reset long-standing energy inequities across the country. If equitably deployed to also benefit vulnerable groups, a new utility system could help historically disadvantaged neighborhoods overcome some environmental injustices. By using an inclusive growth model of sustainable business, long-term resiliency and capital inflow could be achieved simultaneously. However, the technology also has the potential to create deeper environmental injustices if disadvantaged neighborhoods are left behind in the deployment. Those who do not receive access to renewable energy benefits could receive worse offset effects from climate change and decreased economic opportunity.

Thus, this thesis aimed to start a discussion on the relationship between renewable energy and inclusive community-building by exploring residential solar growth and gentrification in San Diego, California. San Diego city has been a solar energy leader in the last few years and demonstrates significant levels of gentrification (Pforzheimer et al., 2020, Richardson et al., 2019), serving as a data-rich setting for my research. Through a case study on the city, I examined the effects of residential solar on the displacement trends from 2013-2020. The following sections detail my study on the question, *what is the effect of residential solar energy on gentrification pressures in San Diego?* The literature review uncovers different factors of residential solar energy and gentrification in both America and San Diego, CA. Then, the methodology section details my mixed methodology approach to examine the research question. Next, the analysis and discussion sections provide my findings, correlations, and limitations. Finally, the conclusion ties all the sections together and recommends future research.

LITERATURE REVIEW

Extensive research on solar energy developed over the last decade, following the dramatic growth rate of the solar energy industry (Solar Industry Research Data, 2020). Some findings indicate an influence of residential solar energy on home value and utility prices (Brinkley and Leach, 2019; Cai et al., 2013). Moreover, broad and interdisciplinary research ties factors of rising home values and utility prices to risks of urban gentrification (Sunter et al., 2019; Wolske, 2020). Gentrification in this study is defined as the introduction of higher-income individuals into a low-income area, causing the displacement of low-income individuals due to forces that push them out or exclude them from entering a specific region (Chapple et al., 2017). Despite the research on solar energy and gentrification, no academic research exists on the relationship between residential solar energy and gentrification. Thus, my study fills this gap by examining the correlation between residential solar energy and the factors for gentrification. The following sections discuss existing academic literature on solar energy and environmental gentrification in the United States. The analysis includes the U.S. solar energy market, residential solar energy, environmental gentrification, and the status of each topic in San Diego, CA (SD).

The United States Solar Energy Market

The U.S. solar energy market is growing at a dramatic rate, with an increase of 23% in 2019 alone (Pforzheimer et al., 2020). The U.S. Energy Information Administration's (EIA) 2020 Energy Outlook Report (Linga, 2020) found that solar energy would be the fastest-growing energy source into 2050. The report proposes that solar energy growth is led by decreasing capital costs and each state's renewable energy goals. A barrier to solar energy deployment derives from the availability and capacity of battery storage, which provides energy when the sun is not present, and high soft costs (labor, inspections, overhead, etc.). However, the growing demand for solar energy is driving greater battery included distribution. SEIA expects 25% of solar energy installations to be paired with battery storage by 2025 (Solar Industry Research Data, 2020).

The U.S. solar energy industry has multiple economic impacts across the United States. As of 2019, 250,000 Americans received employment from solar energy companies, and industry investments generated $18.7 billion for the U.S. economy. While Covid-19 had a large impact on the economy in 2020, industrial solar energy still saw increased growth rates from online sales (*Solar Industry Research Data*, 2020 and The Solar Foundation, 2020). The E.I.A. analyses found the greatest projected growth located in mid-continental and southwest regions (Linga, 2019). California continues to lead with installations; however, growing technologies and policy incentives are shifting more states to include solar energy installations for residential, industrial, and community levels. While solar energy made major financial contributions to the U.S. economy, limited research investigates the effect of solar energy on low-income neighborhoods.

Residential Solar Energy

Three types of solar energy technology exist in the United States: "photovoltaics (PV), which directly convert light to electricity; concentrating solar power (CSP), which uses heat from the sun (thermal energy) to drive utility-scale, electric turbines; and heating and cooling systems, which collect thermal energy to provide hot water and air conditioning” (*Solar Energy Technologies*, 2018). My study focuses on the residential PV and solar thermal heating energy to analyze the neighborhood impact of solar energy. Residential solar energy is defined as installed PV panels or solar thermal on residential buildings or homes (*Solar Energy Technologies*, 2018). This section details the different incentives and demographics of U.S. residential solar energy buyers, as well as the effects of residential solar energy on households.

Residential Solar Energy Customers

In 2019, residential solar energy installation hit a record high as costs declined and state expansion increased (*Solar Industry Research Data*, 2020). EIA predicts an average of 6.1% residential solar energy growth by 2050 (Linga, 2019). However, research suggests the growth varies by different motivations and demographics.

While many environmental and financial incentives exist to install solar energy, academic research examined which factors interest consumers most. Wolske (2020) examined the different motivations of potential solar energy adopters, accounting for median household income and homeownership. The results found similar motivations and interests to install residential solar energy among all ethnic and socioeconomic statuses. The similar motivations to install solar energy were cost savings and environmental impact. In addition, Wolske highlighted an increased disparity gap between early adopters and delayed adopters. On the other hand, actual resident installers differ by race and income. Sunter et al. (2019) found that Black and Hispanic majority census tracts install less solar energy compared to other demographics. The authors note that the difference correlates with research on minorities' lower-income and homeownership.

Thus, despite similar motivations to install solar energy, income and homeownership affect an individual's ability to install, creating the potential for disparities and minority disadvantages.

With recognized barriers to entry, the U.S. Government and solar energy businesses offer low-income individuals and families' incentives to install solar energy. However, each state has different financial tax advantages and assistance programs. The unique financial situations of individuals, like renting households and government program recipients, complicate possible solutions to low-income adoption. Multiple research centers highlight options and recommendations tailored to individuals, including tax deductions and loan programs (Borenstein, 2017; Cook & Bird, 2018; NC Clean Energy Technology Center, n.d.).

The Effects of Residential Solar Energy on Households

Existing research suggests that residential solar energy affects housing prices, utility rates, and peer effects, or the influence of a reference group on an individual's choice. First, Brinkley and Leach (2019) reviewed 54 studies over a 40-year span on all types of energy infrastructure (gas, electric, wind, etc.) to uncover that residential solar energy was the only infrastructure with a correlation to housing price premiums, with premiums ranging from 3% to upwards of 7% (p. 60). These premiums are specifically for the building owners; thus, renters do not realize any home value premium from the solar energy installation. Second, other research shows that PV installations provide lower utility rates than traditional electricity. While this benefits those who install solar, the electric companies maintain the decrease in revenue from customers switching to solar by increasing rates of traditional electricity for the remaining customers (Cai et al., 2013). No other study since 2013 examines this paradox between increased property values and utility feedback loops, causing an area of concern for the developed neighborhood effects since 2013. If housing values and utility rates rise, low-income households without solar energy sources, who are unable to afford the high upfront costs or loan payments, may face negative offset effects.

Finally, evidence also indicates that higher concentrations of residential solar energy cause greater installations from neighbors due to utility price changes and peer effects. A study on Southern California highlights that "higher electricity rates make it more attractive for consumers to adopt PV and cause utility companies to lose more sales. Concerns have been raised regarding the impact of this feedback cycle on non-solar customers" (Cai et al., 2013, p. 842). The study has limits because the authors did not examine the different types of utility price models, like time-of-use rate versus net metering. Peer effects also indicate higher levels of residential solar energy adoption. Bollinger and Gillingham (2012) found that the visibility of solar energy panels and word-of-mouth information sharing both increased the installation rates in California zip codes. The impacts of residential solar energy tend to improve the financial conditions of adopters, yet limited evidence suggests the effect on neighboring households outside of peer effects.

Environmental Gentrification

Prior research found that environmental improvement projects could lead to displacement pressures for gentrification (Anguelovski, et al. 2019; Chapple et al., 2017; Rigolon & Németh, 2020). Studies found that key factors, which drive the risk of gentrification, are census tract changes in rent, income level, race, access to jobs, access to transportation, and percent of populations with a college degree (Chapple et al., 2017).

In the last two decades, existing research examined urban environmental improvement projects' effect on displacement pressures. Rigolon and Nemeth (2020) examined urban park development in ten American cities and found evidence that the location of parks near other displacement factors, including job access and transportation, lead to higher rates of gentrification. The variety of urban locations offers evidence that green infrastructure correlates to gentrification across the country. In another study, Anguelovski et al. (2018) performed a three-part analysis: diagnosis of green development inequalities, political planning methods that reinstate inequalities, and the ramification of green gentrification. The study aimed to identify examples of green gentrification for beautification projects and green infrastructure alike. The authors found that "the marriage of urban redevelopment with greening creates a paradox. Even while greening certainly provides economic, ecological, and social benefits to many, it may create new and deeper vulnerabilities" (p. 1065). Following these findings, a deeper analysis of urban development associated with environmental improvement, including renewable energy, is necessary for displacement reduction and other urban planning challenges.

San Diego, California

For this study, I chose to focus on San Diego, CA because of the city's high solar energy growth and gentrification rates. The city provides rich data to examine the relationship between residential solar energy and displacement pressures (Pforzheimer et al., 2020; Richardson et al., 2019). The following section details the state of solar energy and gentrification in San Diego.

Solar Energy

California continues to be a leading U.S. state in solar energy adoption in 2020. The Shining Cities (2020) report ranked San Diego, CA second for the most PV per capita and total number of PV installations in the country. Furthermore, San Diego aims to generate 100% of its energy from renewables by 2035 (Pforzheimer et al.). To achieve this goal, installations received government support from policies including loan programs, tax exemptions, and building standards. In 2020, the city of San Diego offered five policy incentives, including Property Assessed Clean Energy (PACE), Green Building Incentive Program, Home Energy Renovation Opportunity (HERO), Sustainable Building Policy Expedited Permitting, and California FIRST (NC Clean, n.d.).

The city receives traditional and solar energy services through the local utility company, San Diego Gas & Electric (SDG&E). Solar energy customers receive two bills: one for the renewable energy generator and another for the gas and electric meter—if used. If customers generate more energy than used with solar installations, then SDG&E offers bill rebates through a Net Energy Metering Program (San Diego Gas and Electric, 2021b). Starting in 2022, the city of San Diego will offer residents Community Choice Energy where residents can switch their utility service from SDG&E to the community renewable energy grid. San Diego Community Power sources the renewable energy from solar and wind, and then delivers the electricity through the SDG&E lines to households, using renewable energy without changing the infrastructure or utility costs of the households (San Diego Community Power, 2021).

Some studies indicate housing price premiums from residential solar energy in San Diego. Dastrup et al. (2012) found that environmentally friendly neighborhoods face higher premiums, while all houses faced an average premium of 3-4% through a hedonic study in San Diego. Hoen et al. (2013) examined a large pool of California homes sold from 2000-2009 to estimate the marginal impact of PV solar energy installations on the home sale value. The study finds that PV installations consistently lead to premiums on housing prices. No research in San

Diego examines the neighborhood effects of residential solar energy; thus, this study begins by examining the offset effects of residential solar energy on displacement pressures in San Diego.

Gentrification

The National Community Reinvestment Coalition (2019) ranked San Diego as having one of the highest gentrification rates in the United States since 2000. The report placed San Diego in the top 7 cities with the highest gentrification rate, indicating 29% of eligible census tracts gentrified from 2000 to 2013. The top seven cities, including San Diego, accounted for nearly half of the national gentrification (Richardson et al., 2019). Environmental gentrification studies focus on greening and improvement projects; however, they do not examine renewable energy, limiting their analysis. My study connects existing research discussed in this literature review to analyze whether residential solar energy correlates with the high rates of gentrification in San Diego, CA.

METHODOLOGY

I used a mixed methodology research study to examine the relationship between residential solar energy growth and gentrification occurring between 2000-2018 in San Diego, CA (SD). A mixed methodology research model collects qualitative data in addition to quantitative data to supplement regression findings. Chapple et al. (2017) used a similar model to examine the impact of neighborhood proximity to transportation on gentrification elements (pp. 75-84). By combining the data from the Urban Displacement Project (UDP) and American Community Survey (ACS), I adjusted my variables from transportation proximity to residential solar energy installation count. Then, I ran a bivariate logit regression and neighborhood change comparison table with data from 2012-2018 to identify whether gentrified census tracts correlated with PUMA level residential solar energy growth in San Diego City. Supplementary, I interviewed council members, non-profit employees, community members, and solar energy developers within San Diego, CA. Finally, I ran a qualitative analysis on general observations and themes to more deeply analyze the findings.

Prior research on environmental gentrification also used mixed methodology models to examine the change before and after neighborhood improvement projects (Rigolon & Nemeth, 2020; Chapple et al., 2017). Because there are various studied correlations with gentrification, qualitative insight is necessary to understand the complex neighborhood changes. Additionally, research on the social impact of renewable energy is in its primacy and includes multiple extraneous variables, including payment programs and types of solar. The mixed methodology model contextualized my statistic results to address some confounding and extraneous variable effects. The following section details the data sources, quantitative and qualitative methods, and assessment of the study.

Data Sources

The Urban Displacement Project Data

The Urban Displacement Project studied Los Angeles to understand and identify the dynamic of displacement and gentrification in urban settings across America. The study used data from the 2012-2018 American Community Survey; 1990, 2010, and 2000 Decennial Census; and 2012-2017 Zillow Home Value and Rent Indices to create interactive typology maps. Each typology is categorized based on the criteria of neighborhood change regarding percent degrees, household type and income, race demographics, and home market value (Thomas et al., 2020). The data is publicly available and updated regularly, as data becomes available. As shown in Table 1, the UDP updated the typologies in 2020 to eight key categories of displacement and gentrification.

Table 1

UDP's Displacement Typologies and Criteria

Modified Types	Criteria
Low-Income/Susceptible to Displacement	• Low or mixed low-income tract in 2017
Ongoing Displacement of Low-Income Households	• Low or mixed low-income tract in 2017 • Absolute loss of low-income households 2000-2017
At Risk of Gentrification	• Low income or mixed-low-income tract in 2017 • Housing affordable to low or mixed-low-income households 2017 • Didn’t gentrify 1990-2000 OR 2000-2017

	• Marginal change in housing costs OR Zillow home or rental value increases in the 90th percentile between 2012-2017 • Local and nearby increases in rent were greater than the regional median between 2012-2017 OR the 2017 rent gap is greater than the regional median rent gap
Early/Ongoing Gentrification	• Low income or mixed-low-income tract in 2017 • Housing affordable to moderate or mixed moderate-income households in 2017 • Increase or rapid increase in housing costs OR above regional median change in Zillow home or rental values between 2012-2017 • Gentrified in 1990-2000 or 2000-2017
Advanced Gentrification	• Moderate, mixed moderate, mixed high, high income tract in 2017 • Housing affordable to middle, high, mixed moderate, and mixed high-income households in 2017 • Marginal change or increase in housing costs • Gentrified in 1990-2000 or 2000-2017
Stable Moderate/Mixed Income	• Moderate, mixed-moderate, mixed-high, high income tract 2017
At Risk of Becoming Exclusive	• Moderate, mixed-moderate, mixed-high, high income tract in 2017 • Housing affordable to middle, high, mixed-moderate, and mixed-high income households in 2017 • Marginal change or increase in housing costs

Becoming Exclusive	• Moderate, mixed-moderate, mixed-high, high income tract in 2017 • Housing affordable to middle, high, mixed-moderate, and mixed-high income households in 2017 • Rapid increase in housing costs • Absolute loss of low-income households 2000-2017 • Declining low Income in-migration rate 2012-2017 • Median income higher in 2017 than in 2000
Stable/Advanced Exclusive	• High-income tract in 2000 and 2017 • Affordable to high income households in 2017 • Marginal change, increase, or rapid increase in housing costs

Note. The table was reprinted from "Thomas, T., Driscoll, A., Aguilar, G.P., Hartman, C., Greenberg, J., Cash, A., Zuk, M., and Chapple K. (2020). *urban-displacement/displacement-typologies: Release 1.1* (v1.1) [Computer software]. Zenodo. https://doi.org/10.5281/ZENODO.4356684"

While the data is publicly available for research, this study was not endorsed by the Urban Displacement Project. For my study, I used the criteria variables from the UDP typologies in the neighborhood change comparison table and as controls in my regressions. I also used the data's dichotomous variable for gentrification from 2000-2018 (*gent_00_18_urban*) as my key dependent variable. Finally, the UDP typologies were used to categorize the interview participants by the location of the participant's place of employment. In the discussion section, I mention the interview participants' typology to contextualize the interview results.

American Community Survey Data

The American Community Survey is an annual survey that collects data on the United States' social, economic, housing, and demographic characteristics. The Census Bureau surveys over 3.5 million households across the country each year for the purpose of community and finance planning. (U.S. Census Bureau, 2017).

For this study, the key variables derived from the question, "household heating fuel by tenure". All occupied housing units, owner-occupied or renter-occupied, were asked which fuel they use most to heat the residence. The survey provides the options, gas, electricity, oil, coal, wood, solar, or other fuel (U.S. Census Bureau, 2020, 21). The smallest publicly available data was the PUMA level. PUMAs are non-overlapping statistical geographical areas with no fewer than 100,000 people; these regions are used for annual and 5-year estimates on housing characteristics (U.S. Census Bureau, 2020, 2021). I used 5-year estimates to reduce the margin of error. PUMA level data on heating fuel is not available before 2012; thus, I extracted data for the 5-year estimates of Public Use Microdata Areas (PUMA) in San Diego City, CA from 2012-2018.

This study assumes that increases in solar energy for heating and fuel indicated an overall growth for solar energy in that region. While electricity data would provide a more accurate representation of the solar energy population in San Diego, heating fuel was the only publicly available data. My study did not have sufficient time to acquire the local utility data through the request program. Additionally, PUMAs are currently the smallest publicly available data for the housing characteristic "household heating fuel by tenure". Thus, with this assumption, the data provides insight into the growth changes for solar in the San Diego, CA region.

Quantitative Data Collection

Binary Logit Regression

Before running the regression, the data needed to be sorted and combined. To determine which census tracts are in San Diego City, I used the Missouri State Data Center's MABLE Geocorr tool. The American Community Survey does not offer data on which census tracts or PUMAs reside inside specific cities. The MABLE tool determines which geographies reside inside other geographies (Missouri Data Census Center, 2016). By using the county ID for San Diego County, I extracted the Zip Code, Census Tract, and PUMAs in the city of San Diego. I used the list to determine which census tracts to use from the UDP Los Angeles Data set and which PUMAS to use from the ACS data. Then, I constructed both quantitative analyses.

The binary logit regression used dichotomous variables for gentrification and solar growth in San Diego, CA. The regression was run for the growth in owner-occupied households and renter-occupied households. First, I cleaned the data for missing values and outliers. For the explanatory variable, I created a dichotomous variable from the percent change of residential solar for heat fuel from 2012-2018. PUMA regions that had solar growth higher than the median percent change for all San Diego City PUMAs equaled “1”, while those lower than the median equaled “0”. I used these criteria to create the explanatory variable in each regression: one for owner-occupied households (*highowner*) and one for renter-occupied households (*highrenter*). The dependent variable (*gent_00_18_urban*) is the Urban Displacement Project (UDP) typology variable “gentrification between 2000-2018” from the Los Angeles region dataset. This variable categorizes San Diego City census tracts as ‘gentrification occurring’ between 2000-2018 based on the UDP criteria where gentrification equaled “1” and no gentrification equaled “0”. The criteria for gentrification occurring includes: vulnerable to gentrification in 2000, above median percent college change from 2000-2018, above median percent change for Hispanic population 2000-2018, lost low-income in 2018, negative change in low-income from 2012-2018, and "hot market" in 2018. Then, I controlled for the baseline year (2000) in the experiment with variables from the UDP Los Angeles data set: percent low-income count (*per_all_li_00*), home value (*real_mhval_00*), percent population over 25 with a degree (*per_col_00*), and percent non-white (*per_nonwhite_00*).

With the help of the Howard W. Odum Institute for Research in Social Science, I ran the regressions in SAS to collect the binary logit regression output. For the analysis, I used the three asymptotically equivalent Chi-Square tests and Analysis of Maximum Likelihood Estimates. I used a <0.05 significance level for my p-value to reject the null hypothesis.

Confounding Variable Comparison Table

Because gentrification is a complex issue that correlates with many variables, I created a comparison table to illustrate the different neighborhood changes between high and low solar energy growth areas. I expect that controls in the analysis correlate with gentrification based on the existing research on gentrification pressures; therefore, I analyzed each of these potential confounding variables in isolation with solar energy growth.

With the help of the Howard W. Odum Institute for Research in Social Science, I used SAS to compare the mean and median neighborhood changes for different solar growth levels. The table used the dichotomous variables for high solar growth in owner-occupied and renter-occupied households from the binary logit regression and compared the neighborhood demographic changes from 2012-2018. The neighborhood variables analyzed were change in the low-income count, percent change rent, percent change in home value, percent change in the population aged 25+ with a college degree, and percent change non-white. All change variables were derived from the UDP Los Angeles Region dataset for San Diego City census tracts. Because the solar energy data ranged from 2012-2018, I used UDP data from 2012-2018 when possible. 2012 data was not available for non-white and percent degree holders in the data set; thus, I used the change from 2000-2018 for these variables.

I used the comparison table to look for trends in neighborhood change that align with gentrification. Trends for gentrification show a lower low-income count change, higher percent change in home value and rent, lower non-white change, and higher change in college degree holders. I also took note of any major neighborhood changes between the high and low solar growth PUMA regions with a difference greater than 5%. This difference would suggest the need for a deeper analysis of the specific neighborhood effect and residential solar energy.

Qualitative Data Collection

To provide ground-truthing and control for extraneous variables that correlate with gentrification and solar energy, I conducted ten interviews with San Diego, CA residents. I created a seven-question interview with five questions on solar energy and two questions on gentrification as shown in Table 2. The questions ask the participants' perspective on solar growth and gentrification in San Diego, CA from each sector, both public and private.

Table 2

Qualitative Analysis Interview Questions

Interview Questions
1. Have you noticed any initiatives to prevent gentrification in the area?

2. What perpetuates low-income struggles in the area?
3. How have solar installations affected your community?
4. How effective have solar companies been on making installation accessible?
5. How effective have community members been at being a part of the conversation and decision making on whether solar installation happen on residential properties?
6. What is the relationship between policymakers and solar installations in the area?
7. What more could be done to overcome any negative impacts of solar in your area?

Prior to recruiting participants, I received Institutional Review Board (IRB) approval by expedited review. The letter of exemption is in Appendix B. Then, I recruited participants through networking with connections in the Kenan Institute of Private Enterprise and UNC Kenan-Flagler Business School, LinkedIn searches, and the San Diego City website. Eligible participants included residents aged 18+ with the professions of council members or government officials, non-profit employees, academics, residents, and solar energy company employees. To ensure I had a diversity of participants for quality results in a small sample size study, I used the ArcGIS tool to locate the participant employer's census tract and then determined the census tract UDP typology category from Table 1 (ArcGIS Online, n.d.). I made sure that each eligible profession and census tract typology was represented in the interview participants. I collected a list of over 40 eligible participants and sent a standardized email with the IRB information sheet attached to each person. The final group of ten participants included three government officials, three non-profit employees, three academia members, and one solar energy company employee. Three of the participants' professions cross-listed in more than one of the profession categories. Table 3 details the ten interview participants experience and typology categorization.

Table 3

Interview Participant Categorization

Participant #	Profession	Census Tract Typology
1	Government	Stable/Advanced Exclusive High Student Population
2	Nonprofit/Academia	Stable/Advanced Exclusive
3	Government	At Risk of Becoming Exclusive
4	Government	Becoming Exclusive
5	Nonprofit	Low Income/Susceptible to Displacement
6	Academia	Stable/Advanced Exclusive
7	Nonprofit/Solar	Almost all Typologies
8	Academia	High Student Population
9	Solar	Advanced Gentrification
10	Nonprofit/Solar	Low-Income/Susceptible to Displacement

Each interview was held over Zoom or phone, and the audio was recorded for transcription. Each participant was given a code name based on their profession and census tract typology (ex. Non-profit-becoming exclusive) and I did not use their personal information in the data collection. At the start of each interview before beginning the recording, I requested verbal consent (the waiver of written consent was approved). In the interview, I did not prompt any of the answers or ask follow-up questions outside of the seven interview questions. After each interview, I transcribed the data for analysis. All recordings and transcriptions I stored on my password-protected device for participants' security.

Assessment

Research Scope Justification

I chose to perform a city-level case study because no research exists on my topic and policy incentives differ on a state and local level. As first-of-its-kind research, the focused study examined results with more detailed attention to variables. San Diego's rapid solar growth and high gentrification rates provided rich insight to cities with similar contexts (Pforzheimer et al., 2020; Richardson et al., 2019). Because policy incentives vary by region, I controlled for some extraneous policy variables by focusing on one location (NC Clean, n.d.). Withal, my study's structure is suitable for future research on other cities or comparative studies. If more time were available in my study, the analysis would easily be replicated on any other city from the UDP depository. Alternatively, all the used variables' raw data could all be extracted from the ACS.

Data Limitations

As noted in my literature review, gentrification has multiple correlations with neighborhood change (Anguelovski et al., 2019; Rigolon & Németh, 2020; Chapple et al., 2017). I addressed some of these limitations with additional independent variables in my analysis. The interview portion also added insight to the data findings and helped explain some of the extraneous variables. However, I ran only ten interviews, so the data is neither inclusive of all the community strategies nor populations present in San Diego City, CA.

Second, the publicly available data limited the accuracy of the results. The variable for residential solar energy growth does not represent the full residential solar energy population. The data derives from the ACS question that asks, "what is the heat source you use the most?". Because San Diego, CA has a warm climate, the use of solar energy for heating is limited in count—residents more commonly use solar energy for electrical purposes. Initially, the methodology planned for local utility data; however, the SDG&E formal process took more time than I had available for my study. The local utility San Diego Gas and Electric (SDG&E) offers a third-party consumer data request through an official request process with Privacy GreenLight. I completed the initial request but did not have sufficient time to process the SDG&E data. Details of the request process are in Appendix A. Future research should set aside sufficient time to examine the data from SDG&E solar electricity customers.

Additionally, this study assumed that the change in solar energy at the PUMA level made an impact on the gentrification pressures at the census tract level. Changes on a smaller level could impact the correlation between the variables in question. Further analysis should be run using census tract level data to clarify this assumption.

Finally, the period of the data was quite large to realize the most recent effects of solar change. The gentrification data from UDP was only available for the years 1990, 2000, and 2018. While I chose the two most recent years 2000-2018, the large amount of time in between the baseline and end years permits more extraneous variables for solar growth and gentrification. To describe solar energy growth more accurately in San Diego, data from 2015-2020 would have provided more insightful results because of the city's adoption of a climate action plan in 2015 that pushed the development of new city government and local utility solar energy incentives.

Conclusion

The previous section detailed the methodology to examine the research question, *what is the effect of residential solar energy on gentrification pressure in San Diego, CA?* By using a mixed methodology study based on other neighborhood change studies, this study builds upon existing and credible methodologies. First, this section described the external data sources from the UDP and ACS. Next, this section detailed the quantitative and qualitative data collection, including the IRB approval process to conduct interviews. Finally, the methodology was assessed for limitations and confounding variable minimization.

RESULTS

In this section, I detail the research results. First, I explain the two hypotheses I made on the research question. Following, I describe the regressions and comparison table data from the quantitative analysis. Finally, I explain the results from the qualitative analysis interviews.

Hypotheses

Based on the literature review of solar energy and gentrification research, I created a set of hypotheses on the research question. The two hypotheses below describe my predictions for the relationship between residential solar energy growth and gentrification occurring between 2000-2018 in San Diego, CA (SD).

First, I expected that residential solar energy growth would have a statistically significant relationship with, and increase the probability of, gentrification occurring in San Diego, CA. Prior research found correlations with elements that disproportionately raised costs of living to displace low-income residents. Because some research indicated increased home value for solar adopters and increased utility rates for the non-solar energy outgroup, I predicted that solar energy growth influenced the probability of gentrification to occur.

Second, I predicted to see a different degree of relationship between the residential solar energy growth for renter-occupied households and the residential solar energy growth for owner-occupied households on the outcome variable, gentrification occurring. I assumed that rental units are near one another and set rent prices on the area average. Because more low-income households rent instead of their own homes, I assume that rent changes from solar energy will have a greater impact on the probability for gentrification. Thus, I predicted that solar energy growth for rental-occupied households will increase the probability of gentrification greater than owner-occupied households.

Quantitative Analysis

The following provides an overview of the quantitative analysis results. First, I will detail the two binary logit regressions for renter-occupied and owner-occupied residential solar energy growth. I provided the output from the Testing Global Null Hypothesis and Maximum Likelihood Estimates for each test variable. For any regression that resulted statistically significant, I included the Odds Ratio Estimates for the point estimate of the solar energy variable. The full output for the regression is found in Appendix C. Following the regressions, I highlight key data points in the neighborhood change variable comparison table.

Binary Logit Regressions

Owner-Occupied Households

This regression examined the correlation between high solar energy growth in owner-occupied households on the probability for gentrification to occur between 2000-2018. The regression was run without and with the 2000 baseline control variables low-income count, home value, percent of the population aged 25+ with a college degree, and percent of population non-white. The Global Null Hypothesis output in Table 4.1 displays no statistically significant relationship without controls, but Table 4.2 displays statistical significance for each type of chi-square estimate with the controls. This suggests that the controls have a stronger correlation with gentrification occurring than high owner-occupied solar energy growth.

Table 4.1

Testing Global Null Hypothesis for "Highowner" without Controls

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	0.0221	1	0.8817
Score	0.0220	1	0.8820
Wald	0.0220	1	0.8821

Table 4.2

Testing Global Null Hypothesis for "Highowner" with Controls

Testing Global Null Hypothesis: BETA=**0**			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	28.6761	5	**<.0001**
Score	23.1907	5	**0.0003**
Wald	14.9230	5	**0.0107**

Thus, the data suggest that the growth of residential solar energy in owner-occupied households does not change the probability of gentrification. In Table 5.1 and Table 5.2, the highowner p-value is 0.88 without controls and 0.67 with controls accordingly. These values are greater than the significance value of 0.05; thus, I fail to reject the null hypothesis—no relationship exists between high growth of owner-occupied solar energy and gentrification occurring. While the results are not statistically significant, it is worthy to note the output displays a negative coefficient. The variable trend suggests that areas with owner-occupied solar energy growth greater than the median decreases the probability of gentrification occurring. This trend was found with and without controls.

Table 5.1

Analysis of Maximum Likelihood Estimates for "Highowner" without Controls

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-2.9768	0.3624	67.4538	<.0001
Highowner	1	-0.0866	0.5837	0.0220	0.8821

Table 5.2

Analysis of Maximum Likelihood Estimates for "Highowner" with Controls

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-0.4736	2.9165	0.0264	0.8710
Highowner	1	-0.2987	0.6963	0.1841	0.6679
per_all_li_00	1	7.4669	2.7693	7.2701	**0.0070**
real_mhval_00	1	8.809E-7	3.308E-6	0.0709	0.7900
per_col_00	1	-14.1730	6.8275	4.3092	**0.0379**
per_nonwhite_00	1	-6.1149	2.6556	5.3022	**0.0213**

In the regression with the controls, some controls had a statistically significant relationship with the probability of gentrification. The statistically significant controls were percent low-income, percent of population aged 25+ with a college degree, and percent of population non-white. These variables coefficients were positive, meaning each increased the probability of gentrification occurring. These results are in line with expectations from prior research. After adding the controls to the equation, the p-value decreased and the highowner coefficient estimate increased; nonetheless, the highowner p-value was very large and the null hypothesis remains in effect.

Renter-Occupied Households

This regression examined the correlation between high solar energy growth in renter-occupied households on the probability for gentrification to occur between 2000-2018. The regression was run without and with the 2000 baseline control variables low-income count, home value, percent of the population aged 25+ with a college degree, and percent of population non-white. The Global Null Hypothesis output in Table 6.1 displays statistically significant results under the likelihood ratio and score chi-square tests' criteria with and without controls. However, the p-value is 0.06 without controls under the Wald chi-square test. This value is greater than the significance value of 0.05; thus, I fail to reject the null hypothesis. The growth of residential solar energy in owner-occupied households does not change the probability of gentrification. Table 6.2 shows a statistically significant relationship with the controls, indicating the controls have an impact on the probability of gentrification occurring.

Table 6.1

Testing Global Null Hypothesis for "Highrenter" Without Controls

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	5.6020	1	**0.0179**
Score	4.4759	1	**0.0344**
Wald	3.3706	1	0.0664

Table 6.2

Testing Global Null Hypothesis for "Highrenter" With Controls

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	30.8117	5	**<.0001**
Score	25.6555	5	**0.0001**
Wald	16.0225	5	**0.0068**

Table 7.1 highlights the Maximum Likelihood Estimates for high renter-occupied growth without controls. While the results are not statistically significant under the Wald chi-square, this relationship was statistically significant under the likelihood and score tests, so the relationship is worthy to note. Thus, I included Table 7.2 to show the point estimate without controls. The point estimate is the coefficient for the percent change in the probability of gentrification occurring if a region has high solar energy growth in renter-occupied households. The table shows a positive 6.86% increase in the probability of gentrification to occur in areas with high rental-occupied

solar energy growth. The variable trend suggests that areas with renter-occupied solar energy growth increases the probability of gentrification occurring.

Table 7.1

Analysis of Maximum Likelihood Estimates for "Highrenter" without Controls

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-4.5642	1.0051	20.6206	<.0001
Highrenter	1	1.9251	1.0486	3.3706	0.0664

Table 7.2

Odds Ratio Estimates for "Highrenter" without Controls

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Highrenter	**6.856**	0.878	53.532

Following, the regression was run with the controls to see if the correlation still exists. Table 7.3 details the Maximum Likelihood Estimates test with the controls. The positive trend was found with and without controls. However, with controls, the p-value for highrenter increased to 0.18, and the variable's correlation was no longer statistically significant. Moreover, the regression for the overall equation with the controls was still statistically significant in Table 6.2, but each variable in Table 7.3 is not statistically significant. Thus, the data suggest that there is multicollinearity occurring between the independent variables. Because the variables are not statistically significant in only this regression, the highrenter has a stronger correlation with each independent control variable than the dependent variable, gentrification occurring. To address this claim, I analyzed the variables in a change comparison table.

Table 7.3

Analysis of Maximum Likelihood Estimates for "Highrenter" with Controls

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-1.6536	3.2177	0.2641	0.6073
Highrenter	1	1.5426	1.1475	1.8071	0.1789
per_all_li_00	1	5.6089	2.8662	3.8294	0.0504
real_mhval_00	1	8.002E-7	3.317E-6	0.0582	0.8094
per_col_00	1	-14.2872	7.3173	3.8123	0.0509
per_nonwhite_00	1	-4.8079	2.8552	2.8356	0.0922

Comparison Table

Table 8 reports the mean and median census tract level changes for high and low solar growth in owner-occupied and renter-occupied PUMA regions from 2012-2018. The change variables are change in low-income count, percent change in rent, percent change in home value, percent change in non-white, and percent change in percent of population aged 25+ with a college degree.

Table 8

Neighborhood Change Variable Comparison Table

Neighborhood Change from 2012-2018*								
	High owner		Low owner		High renter		Low renter	
Variable	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Change in low-income count	83.16	62.60	**72.60**	62.18	34.71	20.99	**155.11**	**115.74**
Percent change in rent	57.04	55.30	**64.13**	60.62	60.18	56.32	63.27	**68.73**
Percent change in home value	11.68	9.58	11.37	8.97	12.15	9.76	10.30	8.13
Percent change in non-white	30.02	21.87	25.60	13.54	30.57	24.59	21.47	11.53
Percent change in percent population aged 25+ with a college degree	**73.29**	**48.33**	58.84	39.57	**74.78**	**51.26**	45.95	30.97

Note. Percent change in non-white and percent change in population aged 25+ with a college degree use data from 2000-2018

The owner-occupied columns in Table 8 parallel the data in the regressions; the low-solar regions experienced more change that trends toward gentrification. While owner-occupied solar growth could decrease the probability of gentrification, the regression was not statistically significant. The neighborhood changes are not related to solar energy growth in owner-occupied households.

On the other hand, the renter-occupied results in Table 8 indicate that areas with high-solar energy trend with changes associated with gentrification more than low solar growth areas. The high renter-occupied column saw lower growth in the low-income population, greater home value, and an increased population of degree holders. These trends are consistent with gentrification elements in the Urban Displacement Project (UDP) typology data. The results confirm the regression results; high renter-occupied solar energy growth increased the probability of gentrification occurring.

Worthy to note, both owner-occupied and renter-occupied columns in Table 8 saw a greater increase of college degree holders in high solar energy growth areas. This similarity suggests a potential correlation between the solar energy growth and college degree holders. If this relationship exists, the confounding could have influenced the binary logit regression.

Qualitative Analysis

I ran a thematic and general observation analysis on the interview transcriptions. First, I read through all the transcriptions and annotated key words related to solar and gentrification. Then, I read the data a second time, looking for patterns in answers to each question between interview participants. I created categories for common patterns in each question and then noted how many times each response was given. Table 9 details the results from each interview question with a number after the response pattern to indicate its frequency.

Table 9

Interview Response Patterns and frequencies

Question 1: Have you noticed any initiatives to prevent gentrification in the area?
No: 5 Yes: 3 No response: 2
Question 2: What perpetuates low-income struggles in the area?
Housing Costs: 7 Education/training: 3

System/Market Supply: 3 Culture/Language: 2 Transportation: 3 Systematic Racism: 2
Question 3: How have solar installations affected your community?
Positive: 7 Noticeable Increase: 3 Connected to other environmental issue improvement: 3 Undetermined on impact: 2
Question 4: How effective have solar companies been on making installation accessible?
Payment programs/Tax credits: 2 Non-profits: 2 Grid Alternative: 6 Community Choice Energy: 2 Salesmen amount large: 2 Not aware/None: 3
Question 5: How effective have community members been at being a part of the conversation and decision making on whether solar installation happens on residential properties?
Construction Mandate: 1 Advocacy Groups: 4 Out of their control/association above: 4 Unknown/None: 2
Question 6: What is the relationship between policymakers and solar installations in the area?
SDG&E Lobby: 3 State and Local legislation: 3 Climate Goals: 2

Local planning committee: 3
Question 7: What more could be done to overcome any negative impacts of solar in your area?
Accessibility: 7 Increase amount: 1 Sustainability/Lifecycle: 4 Community Voice: 2 No negatives exist: 3

Finally, I summarized the overall general observations from the patterns and frequency of responses. Most participants did not notice initiatives to prevent gentrification nor negative impacts from solar energy growth in their neighborhoods. The most common response to low-income barriers was high housing and living costs. The most common response to solar energy accessibility was non-profit assistance from Grid Alternatives. Finally, the most common response to what more needs to be done to overcome any negative impacts of solar was increasing the accessibility and overcoming high costs for low-income neighborhoods. Overall, the interview analysis emphasized the large growth of solar and the barrier to entry for low-incomes and renters in SD.

Conclusion

The previous section details the results from the quantitative and qualitative analysis. The quantitative analysis indicated no statistically significant relationship on the gentrification variable in owner-occupied households and inconclusive results in rental-occupied households. Next, the qualitative analysis highlighted the patterns and frequencies of the interview participants. The results indicated trends that align with some gentrification pressures. The next section will analyze the results in further detail to discuss the significant and insignificant trends.

DISCUSSION

The following section discusses and evaluates the results of my two hypotheses and suggests recommendations for future research. I hypothesized that (1) high solar energy growth would increase the probability of gentrification and (2) owner-occupied households will exhibit a different relationship from renter-occupied households. First, I discuss the results from the quantitative data findings. Then, I contextualize the results with the qualitative analysis themes, offering areas of concern and potential prevention. After which, I use the results to suggest future research studies and clarify my limitations. Finally, in the conclusion of the study, the mixed methodology results evaluate the outcome of the hypotheses.

Quantitative Analysis Findings

Significant Findings

Using the p-value significance level of 0.05, high levels of renter-occupied household solar energy growth results were statistically significant in some but not all tests. The trends from the regressions and comparison table indicate that renter-occupied solar growth could increase the probability of gentrification occurring (Table 6.1, Table 8). The trends for a high percent change of college degree holders and low value of low-income count in Table 8 indicate that residential solar energy growth may be excluding low-income from entering, as opposed to causing low-income individuals to leave. This suggests, if adding solar energy to rental properties increases the rent, then only those who can afford the premium can enter the neighborhood. Thus, the potential type of displacement that solar energy growth increases is the probability of "becoming exclusive," under the Urban Displacement Project (UDP) typologies in Table 1. However, further research is needed to analyze this claim.

On the other hand, the three control variables low-income count, percent college degree holders, and percent non-white population correlated strongly with the gentrification variable. These results are expected because gentrification is the introduction of higher-income individuals into a low-income area, influencing the displacement of low-income individuals due to forces that push them out or exclude them from entering a specific region. For instance, an area with a high level of low-income population is more likely to see a greater percent change than an area with a low low-income count.

Finally, the results in Table 8 indicated a potential correlation between the percent change in college degree holders aged 25+ with the solar energy growth variable. In both the highowner and highrenter columns, the percent of college degree holders increased dramatically more in high solar energy growth areas compared to low growth areas. Likewise, in both Table 5.2 and Table 7.3, the percent college degree holder variable had a very minimal difference between the estimate value in each regression. Thus, there may be a correlation between the percent college degree population and high solar energy growth. College degree holders may be more knowledgeable about solar energy benefits and may have a higher probability of high-paying jobs needed to afford solar energy. This claim may highlight a potential relationship for gentrification in a neighborhood by "becoming-exclusive" through a high inflow of college degree holders.

Insignificant Findings

Using the p-value significance level of 0.05, owner-occupied household solar energy growth was not statistically significant. The trends from the regressions and comparison table indicate that owner-occupied solar energy growth could decrease the probability of gentrification occurring; however, the p-value was very large, and the results were not statistically significant. Thus, no clear relationship was found between owner-occupied solar energy growth and the probability of gentrification.

On the other hand, the control variable home-value was not statistically significant in either regression (Table 5.2, Table 7.3). As a baseline control, the starting neighborhood home value probably did not impact the neighborhood changes. An additional noteworthy finding was that the overall equation for highrenter with controls was statistically significant (Table 8); however, each individual variable was not statistically significant (Table 7.3). The results suggest potential multicollinearity between independent variables.

Finally, the change in home-value and the change in percent population non-white did not have a difference greater than 5% in Table 8. The difference in these variables between high and low solar energy growth, in both owner-occupied and renter-occupied regions, was relatively similar. Thus, the minimal difference suggests that no relationship was found between solar energy growth and either home-value or non-white race changes. If this is found statistically significant, then the correlation between solar energy growth and gentrification variables is not mediated by increased home value or culture shifts from race demographic changes.

Qualitative Analysis Findings

The results from the qualitative interview highlighted areas of concern and potential preventative measures of the impact of residential solar energy on gentrification pressures in San Diego, CA (SD). While none of the participants directly mentioned the relationship between residential solar energy and gentrification pressures in San Diego, each mentioned elements related to the relationship. I am not surprised participants did not discuss gentrification connected to residential solar energy deployment because (1) participants were not directly asked about this relationship (2) participants may not have clear evidence because this is a first of its kind study. Nonetheless, when asked about solar energy's deployment, participants discussed themes consistent with gentrification elements, including rising house values and inequitable access. Thus, interview details are worth further discussion because the hypothesis remains inconclusive. This section uses content from individual transcriptions to discuss the interview patterns in two main categories: areas of concern and prevention measures.

Areas of Concern

Increased Housing Costs

Almost all the participants mentioned the SD Energy Implementation Plan that includes a mandate for all new houses in San Diego to include the foundation for solar energy. The installation of solar energy foundations creates extra costs for home developers and raises the value of the house. All participants noted the housing crisis, either mentioning the housing shortage or high cost of living as a struggle for low-income populations. Thus, if new housing inherently becomes more expensive from the mandate, the barrier to entry for low-income populations could increase.

One non-profit worker mentioned that some roofs are unfit for solar energy because of multi-family buildings or inadequate structures for the technology. Renovation projects could make these roofs available for solar. By taking an older, more affordable household and transforming its structure, the resale value or rent could rise. Then, wealthier individuals, who can afford the home, would enter the low-income neighborhood, impacting the culture of the community and encouraging more renovators and adopters to follow. The domino effect of the cost of solar energy installation requirements and renovation processes is worth further attention to avoid raising the cost of living more and potentially displacing low-income households.

Public Conflict of Interests

While some partnerships exist between companies and organizations, unique goals motivate each entity and create a disconnect between SD solar energy deployment. I conducted interviews from both private and public sectors as well as differing levels of organization hierarchy. Participants from government and academia recognized the large growth in solar energy as a positive to achieve the city climate action goal. Some participants noted that low-income communities typically focus their community advocacy on preserving their neighborhoods, securing jobs, and paying rent, rather than investing in solar energy. Thus, the solar nonprofit mentioned mainly focused on advocating and deploying solar energy to low-income groups with high energy burdens. Finally, multiple participants mentioned the conflicting goals from the local utility, SDG&E, and California Energy Commission. The private sector companies had greater resistance to solar energy adoption strategies to maintain revenues for the traditional utility. One participant noted, while the company had an equity branch, "they're not connected to the folks that are making the decisions and connected to the bottom line." Thus, with each sector having different expectations for solar energy, the disconnect between each group is an area of concern for equitable deployment.

Inability to Access Residential Solar Energy

Despite the rapid growth in solar energy in SD city, low-income neighborhood respondents noted the lack of solar energy in their areas. Residential solar energy deployment is dependent on homeowner ability. Because low-income individuals are more likely to rent and/or live in multi-level housing, there is a greater chance that adding solar energy to their property is not their decision. Some participants indicated that renters have no authority to choose residential solar energy. Alternatively, if the household owner decides to add solar energy, the renter faces higher rent prices to receive lower utility bills. A solar energy option is needed for rental residents to access the benefits of solar energy and avoid potential cost burdens from being left off the solar energy grid.

Prevention Measures

The equitable solar energy distribution in San Diego, CA seems dependent on intentional connections with community members. Overall, residential solar energy has increased rapidly in SD because of the climate action plan and encouraging policy initiatives; however, the equitable deployment seems driven by local organizations and community wide initiatives that work directly with the San Diego City residents.

Community and Non-profit Assistance

First, some participants mentioned that individuals' awareness of policy incentives made an impact on the household's participation in the solar energy industry. Many noted that policymakers helped spread awareness of the different incentives for investing in solar energy while non-profits helped overcome barriers to access.

In almost every interview, the participants mentioned the local non-profit, Grid Alternatives, as the successor for making installation equitable and accessible for low-income populations. Many noted that the non-profit, Grid Alternatives, acted as an advocate and educator, on top of its financial assistance. Thus, Grid Alternatives provides an active voice in the SD community to ensure that low-income neighborhoods understand and receive access to solar energy. This constant communication is potential prevention to inequitable deployment based on its consistent cross-sector work with the community, government, and local utility company.

Community Solar Energy

The community solar energy California Clean Energy (CCE) recently developed in San Diego city. For those who cannot obtain solar energy based on income, homeownership, or multi-family housing, the CCE created a communal grid option that residents can opt into. This energy source may overcome the areas of concern for the inability to access solar energy and increased housing costs. However, concerns remain based on the offset effects for households that remain with traditional utilities. Policymakers may need to set regulations based on utility price changes and rent caps based on household changes to solar energy.

Suggestions

Based on the inconclusive relationship between renter-occupied solar energy growth and gentrification occurring, future research should study a diverse set of cities against multiple sensitivity variables. Like the Rigilon and Nemeth (2020) "just green enough" method, an empirical multivariate study should examine multiple cities with multiple different explanatory variables. This methodology investigates different elements of the variable in question to determine at what degree gentrification occurs if the relationship exists. For instance, the explanatory variables for residential solar energy could be recent growth versus old growth, rent assistant program availability, renter-occupied versus owner-occupied, community solar energy availability, etc. By comparing the different variables related to solar and accessibility, the relationship between residential solar energy and gentrification would be better understood.

Additionally, interviews should be held with a larger sample and in more at-risk areas. While solar is growing rapidly in areas with existing high-income populations, the areas of concern are worth further attention. Stakeholder interviews in at-risk regions could expand the data results on a more granular level. Gentrification is a complex issue that creates winners and losers. While the community receives neighborhood improvements and higher quality resources and jobs, the higher prices may cause individuals who lived there historically to be forced to leave. The changes in culture and prices create a divide between low- and high-income households. The additional information from the community would add insight on whether solar energy is creating new divides in the area and causing historic neighborhoods to change. Thus, a larger sample size of participants could offer new insight into vulnerable neighborhoods.

If the trends in the data for renter-occupied household's solar energy growth are found statistically significant in additional research, a community solar energy grid and non-profit assistance should be prioritized in urban settings. The significant relationship would suggest that renter-occupied residential solar energy deployment creates financial incentives for homeowners and/or creates negative effects on the outgroup, creating greater divides between high- and low-income residents and leading to the negative impacts of gentrification. Alternative to private residential solar energy, a shared solar energy grid that does not create inequitable incentives for those with high income individuals, who can afford the high upfront costs, should be deployed for renter-occupied households. In the case this is not feasible, more investment should be made into non-profit assistance to push deployment of solar energy into vulnerable neighborhoods to preserve the social and economic ability of these communities.

Limitations

The study is limited by the available data. First, the study examined a single city to control for extraneous variables. As a result, the results are biased to the conditions of San

Diego, CA. To better understand the impact of solar energy growth in urban settings, the research would need to be repeated in other cities in the United States. The current study is repeatable for any of the cities in the UDP depository. Cities not included in the depository would need to extract data on neighborhood conditions from the American Community Survey (ACS). Solar energy growth is also available in other United States cities at the PUMA level.

On the other hand, as noted in the methodology, the solar energy growth variable is limited by its sample size and geographical representation. First, the ACS heating fuel question is not the best data for San Diego solar energy use for heating fuel is not as common as in other areas of the United States. Also, while the neighborhood change variables represented the census level, the solar energy growth represented the PUMA level geographical regions. Thus, the data are not representative of the entire residential solar energy population in San Diego, CA.

The sample size and methodology limited the qualitative analysis. Only ten residents participated in the interviews. While the participants covered a wide variety of perspectives, research could derive more insight from a larger sample size because the study is not representative of all strategies and conditions in San Diego, CA or cities in the United States. On the other hand, the analysis involved a thematic analysis instead of coding the responses. Personal bias could have limited the analysis of the interview data. Future research should increase the sample pool and code the data for more sound results.

Conclusion

The results indicate three things about the research hypotheses: (1) high solar energy growth in owner-occupied households and the probability of gentrification occurring in San Diego is not a statistically significant relationship, (2) the relationship between high solar energy growth in renter-occupied households and the probability of gentrification occurring in San Diego is inconclusive and deserves more attention, (3) and there are different results between owner-occupied solar energy growth and renter-occupied solar energy growth in San Diego.

More research is needed to understand the relationship between solar energy growth and gentrification in San Diego, CA and other cities. While the qualitative interviews added insight about areas of concern and preventative measures, further analysis should be done using the local utility data from more recent years. Nonetheless, policymakers, solar businesses, and nonprofits should take note of the findings in this study to make educated decisions on residential solar energy deployment. To make sustainable investments sustainable, the city should consider the social implications highlighted in this study when investing in renewable energy.

APPENDIX A

The process for requesting customer data form San Diego Gas & Electric. The Energy Data Access requires four key certifications for academic researchers:

(1) Project must be certified to be in compliance with "Common Rule" for protection of human subjects by an Institutional Review Board (National Science Foundation's Code of Federal Regulations 45CFR690)

(2) Project must demonstrate compliance with provisions of Civil Code 1798.24(t)(1) when seeking personally identifiable information

Note. Requesters should take note of Civil Code 1798.24(t)(1) which is California state specific. Those located outside of California may need to submit an additional institutional review board submission for the state the data is being requested form.

(3) A signed Model Non-Disclosure Agreement.

Note. Requesters should note that the NDA is non-negotiable. Communication between the research institution and third-party data release company needs to agree on terms before approval.

(4) Valid evidence that the research project advances understanding of California energy use & conservation (San Diego Gas & Electric, 2021a).

After the criteria is sent, the processing time for data is ~45 days. Researchers should make note of the data request process well in advance to receive the needed data. Additionally, while details may differ, a similar level of security protocol and processing is used for other utility companies.

APPENDIX B

Institutional Review Board Letter of Approval for Qualitative Interviews

THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

OFFICE OF HUMAN RESEARCH ETHICS
720 Martin Luther King, Jr. Blvd.
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CB #7097
Chapel Hill, NC 27599-7097
(919) 966-3113
Web site: ohre.unc.edu
Federalwide Assurance (FWA) #4801

To: Jessie LaMasse and Jeffrey Mittelstadt
Carolina Center for Public Svc

From: Non-Biomedical IRB

Approval Date: 12/23/2020
UNC Administrative Review Due Date : 12/22/2021
RE: Notice of IRB Approval by Expedited Review (under 45 CFR 46.110)
Submission Type: Initial
Expedited Category: 5.Existing or non-research data,6.Voice/image research recordings,7.Surveys/interviews/focus groups
Study #: 20-3084

Study Title: Jessie LaMasse's Honors Thesis: The Relationship between Residential Solar Energy and Gentrification in San Diego California

This submission, Reference ID 314881, has been approved by the IRB. It has been determined that the risk involved in this research is no more than minimal. **This research requires annual UNC administrative review.** Under the revised 'Common Rule' of 2018, this study does not require continuing review and IRB approval will not expire.

Study Description:

Purpose: The interview study aims to contextualize the quantitative portion of my study. My thesis examines the impact of residential solar on gentrification in San Diego, CA. Because there are multiple correlations with gentrification, I aim to control for some of the potential confounding vairables with interviews of key stakeholders on the impact of solar in their city.

Participants: Relevant participants impacted my residential solar development will be interviewed, including council members or government officials, community non-profits, building developers, community members and solar companies. Roughly, 10 participants will be interviewed.

Procedures (methods): The study will be a virutal interview through zoom or telephone. The participants will be asked a series of questions related to their relationship with residential solar energy in San Diego California. The interview will be recoreded for transcription and analysis.

Study Regulatory and other findings:

The IRB has determined that the study-specific rationale provided by the investigator is sufficient to justify the waiver of informed consent according to 45 CFR 46.116(d) for the qualitative analysis.

Submission Regulatory and other findings:

As a reminder, although the UNC-Chapel Hill OHRE/IRB may have approved or made a determination that this study can commence, at this time UNC-Chapel Hill in response to direction from the UNC System Office has reduced campus activity significantly due to the COVID-19 outbreak. All human subject research activities are expected to follow all institutional and UNC Health policies, including those that may limit direct contact of participants. If you need to modify or alter your study design due to COVID-19 in order to

conduct your research activities, please submit a modification and advise in the "Cover page" that this is "COVID-19 Related".

Investigator's Responsibilities:

As an institution accredited by the Association for the Accreditation of Human Research Protection Programs (AAHRPP), all research approved under expedited procedures must receive an administrative review at least annually. It is the Principal Investigator's responsibility to submit a UNC administrative review report as requested by the IRB. Failure to respond to this request is considered non-compliance with IRB requirements and University policies.

Your approved consent forms and other documents are available online at
http://apps.research.unc.edu/irb/index.cfm?event=home.dashboard.irbStudyManagement&irb_id=20-3084

You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented.

New Safety Information should be reported to the IRB, in IRBIS, as per OHRE SOP 1401

Please be aware that additional approvals may still be required from other relevant authorities or "gatekeepers" (e.g., school principals, facility directors, custodians of records).

The current data security level determination is Level II. Any changes in the data security level need to be discussed with the relevant IT official. If data security level II and III, consult with your IT official to develop a data security plan. Data security is ultimately the responsibility of the Principal Investigator.

This study was reviewed in accordance with federal regulations governing human subjects research, including those found at 45 CFR 46 (Common Rule), 45 CFR 164 (HIPAA), 21 CFR 50 & 56 (FDA), and 40 CFR 26 (EPA), where applicable.

APPENDIX C

SAS Regression Outputs

Appendix C.1

"Highowner" Binary Logit Regression Output without Controls

The LOGISTIC Procedure

Model Information		
Data Set	FOO._USE_	
Response Variable	gent_00_18_urban	gent_00_18_urban
Number of Response Levels	2	
Model	binary logit	
Optimization Technique	Fisher's scoring	

Number of Observations Read	277
Number of Observations Used	277

Response Profile		
Ordered Value	gent_00_18_urban	Total Frequency
1	0	264
2	1	13

Probability modeled is gent_00_18_urban='1'.

Model Convergence Status
Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics		
Criterion	Intercept Only	Intercept and Covariates
AIC	106.916	108.894
SC	110.540	116.142
-2 Log L	104.916	104.894

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	0.0221	1	0.8817
Score	0.0220	1	0.8820
Wald	0.0220	1	0.8821

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-2.9768	0.3624	67.4538	<.0001
Highowner	1	-0.0866	0.5837	0.0220	0.8821

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Highowner	0.917	0.292	2.879

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	24.9	Somers' D	0.021
Percent Discordant	22.9	Gamma	0.043
Percent Tied	52.2	Tau-a	0.002
Pairs	3432	c	0.510

Appendix C.2

"Highowner" Binary Logit Regression Output with Controls

The LOGISTIC Procedure

Model Information		
Data Set	FOO._USE_	
Response Variable	gent_00_18_urban	gent_00_18_urban
Number of Response Levels	2	
Model	binary logit	
Optimization Technique	Fisher's scoring	

Number of Observations Read	277
Number of Observations Used	277

Response Profile		
Ordered Value	gent_00_18_urban	Total Frequency
1	0	264
2	1	13

Probability modeled is gent_00_18_urban='1'.

Model Convergence Status
Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics		
Criterion	Intercept Only	Intercept and Covariates
AIC	106.916	88.240
SC	110.540	109.984
-2 Log L	104.916	76.240

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	28.6761	5	<.0001
Score	23.1907	5	0.0003
Wald	14.9230	5	0.0107

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-0.4736	2.9165	0.0264	0.8710
Highowner	1	-0.2987	0.6963	0.1841	0.6679
per_all_li_00	1	7.4669	2.7693	7.2701	0.0070
real_mhval_00	1	8.809E-7	3.308E-6	0.0709	0.7900
per_col_00	1	-14.1730	6.8275	4.3092	0.0379
per_nonwhite_00	1	-6.1149	2.6556	5.3022	0.0213

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Highowner	0.742	0.189	2.904
per_all_li_00	>999.999	7.684	>999.999
real_mhval_00	1.000	1.000	1.000
per_col_00	<0.001	<0.001	0.453
per_nonwhite_00	0.002	<0.001	0.403

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	88.7	Somers' D	0.773
Percent Discordant	11.3	Gamma	0.773
Percent Tied	0.0	Tau-a	0.069
Pairs	3432	c	0.887

Appendix C.3

"Highrenter" Binary Logit Regression Output with Controls

The LOGISTIC Procedure

Model Information		
Data Set	FOO._USE_	
Response Variable	gent_00_18_urban	gent_00_18_urban
Number of Response Levels	2	
Model	binary logit	
Optimization Technique	Fisher's scoring	

Number of Observations Read	277
Number of Observations Used	277

Response Profile

Ordered Value	gent_00_18_urban	Total Frequency
1	0	264
2	1	13

Probability modeled is gent_00_18_urban='1'.

Model Convergence Status
Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	106.916	103.314
SC	110.540	110.562
-2 Log L	104.916	99.314

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	5.6020	1	0.0179
Score	4.4759	1	0.0344
Wald	3.3706	1	0.0664

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-4.5642	1.0051	20.6206	<.0001
Highrenter	1	1.9251	1.0486	3.3706	0.0664

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Highrenter	6.856	0.878	53.532

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	33.6	Somers' D	0.287
Percent Discordant	4.9	Gamma	0.745
Percent Tied	61.5	Tau-a	0.026
Pairs	3432	c	0.643

Appendix C.4

"Highrenter" Binary Logit Regression Output with Controls

The LOGISTIC Procedure

Model Information		
Data Set	FOO._USE_	
Response Variable	gent_00_18_urban	gent_00_18_urban
Number of Response Levels	2	
Model	binary logit	
Optimization Technique	Fisher's scoring	

Number of Observations Read	277
Number of Observations Used	277

Response Profile		
Ordered Value	gent_00_18_urban	Total Frequency
1	0	264
2	1	13

Probability modeled is gent_00_18_urban='1'.

Model Convergence Status
Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics		
Criterion	Intercept Only	Intercept and Covariates
AIC	106.916	86.104
SC	110.540	107.848
-2 Log L	104.916	74.104

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	30.8117	5	<.0001
Score	25.6555	5	0.0001
Wald	16.0225	5	0.0068

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-1.6536	3.2177	0.2641	0.6073
Highrenter	1	1.5426	1.1475	1.8071	0.1789
per_all_li_00	1	5.6089	2.8662	3.8294	0.0504
real_mhval_00	1	8.002E-7	3.317E-6	0.0582	0.8094
per_col_00	1	-14.2872	7.3173	3.8123	0.0509
per_nonwhite_00	1	-4.8079	2.8552	2.8356	0.0922

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
Highrenter	4.677	0.493	44.327
per_all_li_00	272.841	0.991	>999.999
real_mhval_00	1.000	1.000	1.000
per_col_00	<0.001	<0.001	1.056
per_nonwhite_00	0.008	<0.001	2.199

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	89.7	Somers' D	0.794
Percent Discordant	10.3	Gamma	0.794
Percent Tied	0.0	Tau-a	0.071
Pairs	3432	c	0.897

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