University of Chicago

Access to Rooftop Solar in Chicago: The Effectiveness of Policy to Increase Solar Adoption for Lower-Income Households

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ENST 25012
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March 9, 2023

Abstract

This paper examines the distribution of rooftop solar installations in Chicago and the factors that influence their adoption, with a particular focus on equity. Despite the many benefits of solar panels, including reduced energy costs and decreased greenhouse gas emissions, many households in the United States, especially those with low incomes and minority populations, face barriers to obtaining affordable solar electricity. The paper uses publicly available data sources and GIS software to map the distribution of building permits for solar panel installation in Chicago over time and compare them with community area income levels. The study finds that income levels have been a significant factor in the adoption of rooftop solar in Chicago, with solar panels initially clustered in high-income areas. However, policy measures implemented since 2016, such as The Future Energy Jobs Act and Illinois Solar for All, have been effective in increasing equitable adoption, although penetration rates remain low in very low-income populations. The analysis demonstrates the importance of policy that aims to increase the equitable adoption of solar panels, especially for disadvantaged communities, and provides insights for policymakers and stakeholders interested in promoting solar energy adoption in urban areas.

Introduction

There are many benefits to rooftop solar installations for homeowners, landlords, and the environment. For example, solar panels can reduce energy costs, increase home values, and decrease greenhouse gas emissions. One study by Lawrence Berkeley National Laboratory showed that on average, solar increased the value of a home by about $15,000, and energy savings can be in the tens of thousands over a 20-year period. Additionally, the cost of solar installation has fallen dramatically over the past decade.[1] Tax credits and incentives on the federal, local, and state levels for homeowners who install photovoltaic panels can also help reduce the system's upfront cost and make it more affordable.

Despite decreased expenses associated with solar energy systems, many people in the United States cannot obtain affordable solar electricity, particularly renters and homeowners who have difficulty accessing reasonable financing options. In 2019, out of the households that

[1] Adomatis, Sandra, and Ben Hoen. "Appraising into the Sun: Six-State Solar Home Paired-Sales Analysis." *Lawrence Berkeley National Laboratory*. (2015). 9.

adopted solar, only 31% belonged to the category of earning less than the area median income[2]. Furthermore, census tracts where Black and Hispanic populations make up the majority exhibit 30% and 69% lower adoption of rooftop photovoltaic (PV) systems, respectively, in comparison to the average census tract.[3] The problem of equitable access to solar panels is situated within a broader context of unequal access to green amenities among communities with a higher percentage of low-income households and minority populations.

The city of Chicago provides a perfect site to explore access to solar energy, as Chicago has a deep history of racial and economic segregation as a result of discriminatory practices, such as redlining. Additionally, the state of Illinois and the city of Chicago have introduced policies to increase equitable access to solar panels, including The Future Energy Jobs Act and Illinois Solar for All. However, there is limited up-to-date research and data on current rooftop solar penetration in Chicago to determine how these policies have affected equitable adoption. To bridge this gap in information, I have mapped the distribution of building permits for the installation of solar panels in Chicago over time in comparison with community area income levels. In this paper, I will explore what factors influence the distribution of solar panels in Chicago to determine if they are unequally distributed, and I will investigate how policies have influenced the adoption of rooftop solar.

Literature Review

In the last decade, cities worldwide have increasingly prioritized sustainability in their planning goals, with many implementing policies and initiatives aimed at reducing carbon emissions, improving air and water quality, and promoting renewable energy. This trend has been driven by concerns about climate change, as well as the desire to create more livable, healthy, and resilient communities. Cities have pursued a variety of strategies to achieve sustainability goals, including investing in public transportation, promoting energy-efficient buildings, expanding green spaces, and increasing renewable energy sources.[4] However, research has shown that many green amenities are often only accessible to certain demographics, routinely

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[2] Barbose, Galen L., et al. “Income Trends among US Residential Rooftop Solar Adopters”. *Lawrence Berkeley National Laboratory*. (2020). 12.
[3] Sunter, Deborah A., et al. “Disparities in rooftop photovoltaics deployment in the United States by race and ethnicity.” *Nature Sustainabilit*y. (2019). 1.
[4] Wolch et al. “Urban green space, public health, and environmental justice: The challenge of making cities ‘just green enough.” *Landscape and Urban Planning.* (2014). 234-244.

excluding lower-income communities.[5] These disparities reinforce existing inequalities in health and well-being and hinder the ability to create resilient cities.

Currently, most of the research analyzing access to green amenities has focused on green space specifically. The literature analyzing the distribution of rooftop solar exists within a broader context of access to green space. Specifically, researchers have shown that access to higher quantities of green space increases perceived mental health, all-cause mortality, and perceived general health.[6] However, data has shown that white-majority areas in Chicago have much better urban green space access compared to minority-dominated areas.[7]Additionally, lower-income neighborhoods have less access to green space than higher-income neighborhoods.[8] Therefore, many of the vast benefits of urban greening initiatives are not available to lower-income Black and brown communities.

There are many theories positing why there is a gap in access to green amenities. First, property developers often invest in green infrastructure as a way to increase property values in luxury neighborhoods, which routinely excludes lower-income neighborhoods.[9] Additionally, Black and brown communities have been historically subjected to discriminatory land-use policies and zoning practices, which have resulted in the concentration of pollution and environmental hazards in low-income and minority neighborhoods, and a lack of investment in green amenities, such as rooftop solar and green spaces.[10]

Similar to green spaces, rooftop solar provides many benefits for homeowners and community members. These benefits can be broken down into two main types: public and private. The main public benefits of rooftop solar, and renewable energy more broadly, include reducing emissions, mitigating climate change, and improving air quality by replacing electricity generators that emit pollutants.[11] By displacing traditional fossil fuel energy sources with solar energy, the public health risks and potential for environmental destruction due to climate change could be mitigated. The primary private benefit of PV (photovoltaic) installations is financial. In return for paying the upfront or ongoing cost of the system, home, and business owners can

[5] Wolch et al. (2014). 234-244.
[6] Van den Berg et al. "Health benefits of green spaces in the living environment: A systematic review of epidemiological studies." *Urban Forestry & Urban Greening*. (2015). 1.
[7] Liu et al. "Analysis of urban green space accessibility and distribution inequity in the City of Chicago." (2021). *Urban Forestry & Urban Greening*. 8.
[8] Liu et al. (2021). 8.
[9] Wolch et al. (2014). 234-244.
[10] Graf, Carly. "Chicago's Green Space: Inequitable for 100 years". *Medill Reports Chicago*. (2019).
[11] U.S. Department of Energy. "Solar Futures Study." *National Renewable Energy Laboratory*. (2021). 79.

reduce monthly utility bills and benefit from an increase in property values.[12] Additionally, in some states, PV consumers can benefit from net metering, which allows PV users to sell their excess solar energy back to the grid at the same rate they pay for their purchased grid electricity.[13] Rooftop solar can also create more resiliency as community members are able to use their own produced energy during a grid outage.[14]

As a result of the push to make more sustainable and resilient cities, rooftop solar has taken off in the last couple of years. Data from the U.S. Energy Information Administration shows that residential solar power installations increased by 34% from 2.9 gigawatts in 2020 to 3.9 gigawatts in 2021.[15] A combination of factors such as reduced costs due to technological advances, federal tax incentives and credits, and state policy support have fueled the rapid growth of solar deployment in the past decade.

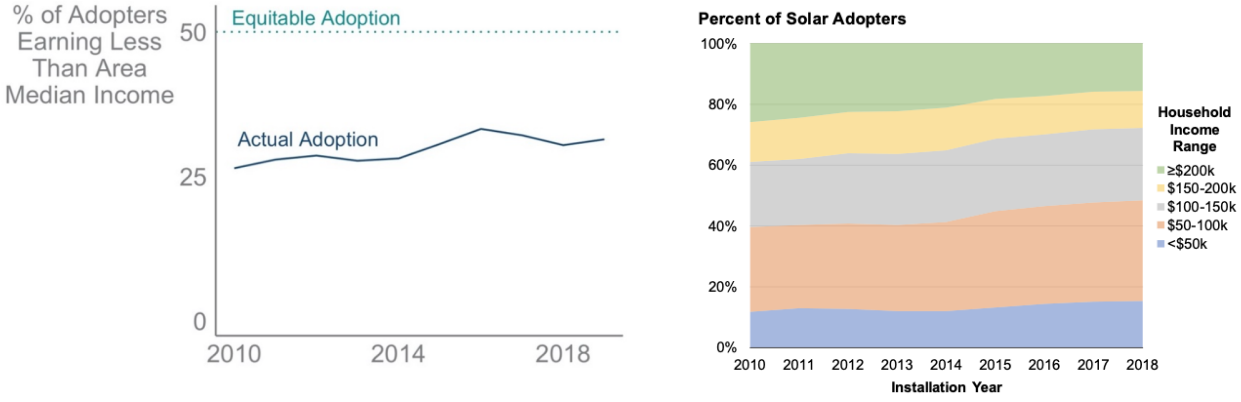

Fig. 1. Percentage of PV adopters earning less than their area median income over time (Left).
Fig. 2. PV adoption rates by household income levels over time (Right).

Despite the growing rates of adoption, the benefits of PV installation have not been distributed equitably across different income, race, and demographic groups, due to uneven adoption patterns.[16] Figure 1 demonstrates what equitable adoption of PV would look like in terms of income levels, compared to what actual adoption has been.[17] Households with rooftop solar tend to have higher incomes than the average U.S. household, and adoption is concentrated among single-family owner-occupied homes, as these households have control over their

[12] U.S. Department of Energy. (2021). 81.
[13] U.S. Department of Energy. (2021). 88.
[14] U.S. Department of Energy. (2021). 81.
[15] U.S. Energy Information Administration. "Annual Photovoltaic Module Shipments Report". (2021).
[16] U.S. Department of Energy. (2021). 89.
[17] U.S. Department of Energy. (2021). 82.

rooftops and are motivated to invest in solar due to the cost-saving benefits.[18] In contrast, tenant households may lack the incentives to install solar due to split incentives between the owner and the renter. Additionally, rooftop solar requires a significant initial investment, which often poses a barrier to lower-income households.

Because of unequal adoption rates, policies and incentives have been implemented by states to increase solar adoption among low-income and minority households. Figure 2 shows how over time, solar adoption has become more equitable as lower-income households gain a larger share of overall solar adoption.[19] Programs targeting Low-to-Moderate Income (LMI) households and financial incentives that decrease the upfront installation cost could be one of the drivers of this shift. These policies are critical, as rooftop solar has the potential to be especially beneficial to minority and low-income households to decrease their energy burden. Data has illustrated that LMI households and households of color experience a disproportionately high energy burden, as they allocate more of their household income towards energy expenses compared to high-income households.[20] PV installation could decrease this energy burden by allowing LMI households to spend less on their energy bill by using their own generated power.

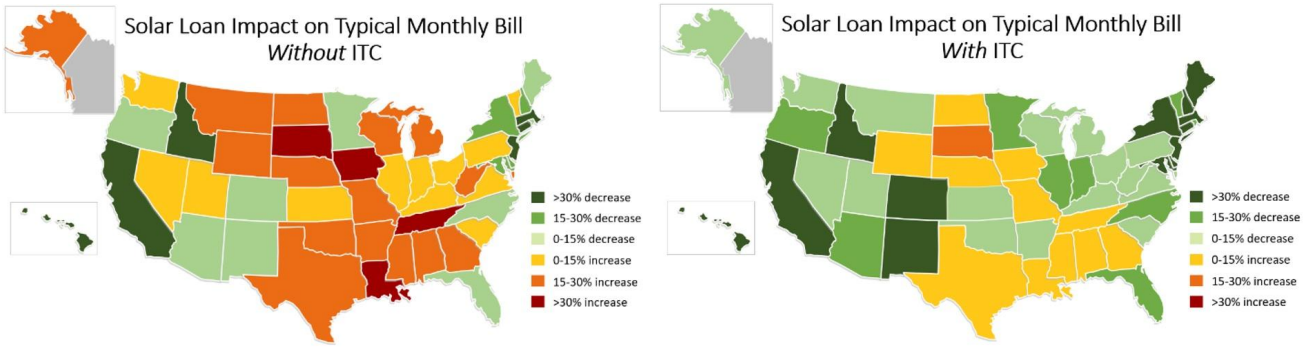

Fig. 3. The percentage difference in monthly energy bill by state with a solar loan before (left) and after (right) the ITC.

However, the upfront cost of installation means that most LMI households need loans to finance the project, which could have the opposite effect than intended on household energy burdens. Figure 3 demonstrates the importance of incentives for LMI households, by showing the impact that a loan for a solar development would have on a typical monthly utility bill, with

[18] Barbose, Galen L., et al. (2020). 11.
[19] Barbose, Galen L., et al. (2020). 14.
[20] U.S. Department of Energy. (2021). 83.

and without the Investment Tax Credit (ITC).[21] The ITC is a federal tax credit that incentivizes the installation of solar energy systems by allowing the system owner to deduct a portion of the system's cost from their federal income taxes.[22] In Illinois, the typical monthly bill would increase an average of 0-15%, but with the ITC, the monthly bill could decrease by 15-30%.[23] Until the upfront cost of installation becomes more affordable, these incentives are critical for adoption among LMI neighborhoods. The state of Illinois and the city of Chicago also have specific incentives and programs to increase solar adoption in LMI communities and communities of color, which will be outlined in the next section.

Chicago has an especially large gap in energy burden among minority and LMI populations, compared to the median energy burden. In the Chicago metropolitan area, the average energy burden is 2.7%, while low-income households spend 8.0% of their income on home energy bills, and Black households spend 4.1%.[24] Despite this disparity, limited research has been conducted in Chicago to measure the distribution and access to rooftop solar.

The most comprehensive study was conducted in 2020 and compares LMI adoption rates between Riverside and San Bernardino, California, Washington, DC, and Chicago, Illinois.[25] As of 2015, Chicago had the lowest total rooftop solar penetration of all four cities, at 0.3%, even though more than half (55%) of single-family households in the city are estimated as solar-suitable.[26] In Chicago, the areas with the greatest potential for rooftop installations were found to be those with higher percentages of LMI households, rather than those with the highest incomes, however, this did not translate into greater adoption of rooftop installations, as can be seen in Figure 4.[27] Because LMI households in Chicago have the greatest potential for PV installation, lower penetration of solar in those neighborhoods significantly diminishes the potential for achievement of renewable energy and energy equity objectives.

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[21] Bourgoin, Courtney. "Advancing Energy Equity and Climate Solutions in Chicago." *Chicago Policy Review*. (2022).
[22] Bourgoin, Courtney. (2022).
[23] Bourgoin, Courtney. (2022).
[24] American Council for an Energy-Efficient Economy. "Energy Burdens in Chicago". (2020). 1.
[25] Reames, Tony. "Distributional disparities in residential rooftop solar potential and penetration in four cities in the United States." *Energy Research & Social Science*. (2020).
[26] Reames, Tony. (2020). 4.
[27] Reames, Tony. (2020). 4-7.

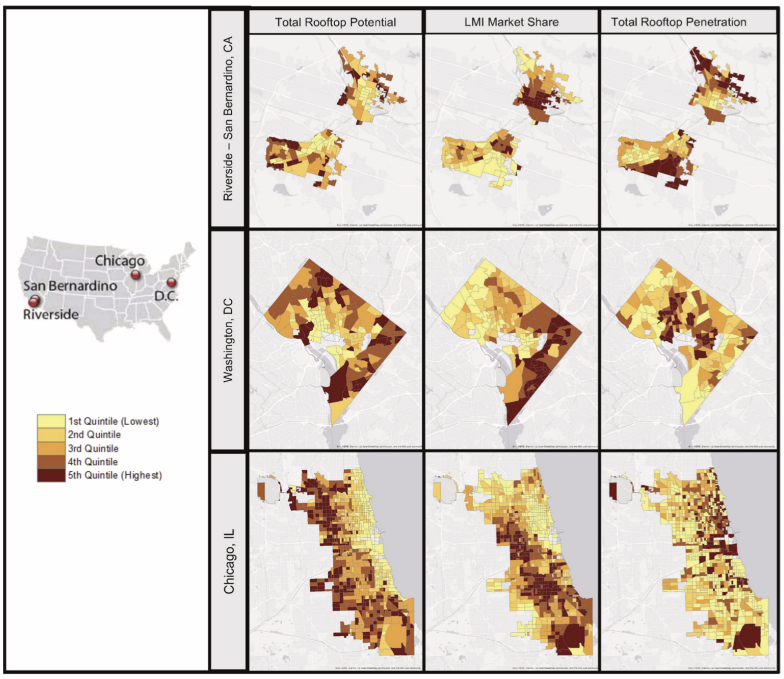

Fig. 4. Quintile spatial distribution of census tract-level (1) total rooftop potential (proportion of rooftops that are solar suitable), (2) LMI market share (proportion of solar suitable rooftops that are LMI-occupied), and (3) total rooftop penetration (proportion of solar suitable rooftops with solar) in Chicago (bottom).

It is important to note, however, that the data used in this study was from 2015, and penetration in Chicago has increased significantly since then, due to a variety of policy initiatives, including Illinois Solar For All, which was enacted in 2019.[28] The Illinois Solar For All program, which will be summarized in more detail in the following section, focuses on expanding adoption in LMI and environmental justice communities, so LMI adoption could have increased as a result of this policy.[29] Therefore, there is a gap in the literature in describing the current landscape of rooftop PV in Chicago and explaining how recent policy changes have influenced the rate of solar penetration and the equity of distribution in Chicago. In this paper, I will attempt to bridge this gap by using up-to-date data to explore rates of adoption and the distribution of adoption in terms of income level, minority level, household ownership rates, and solar potential.

[28] Reames, Tony. (2020). 3.
[29] Reames, Tony. (2020). 3.

Local, State, and Federal Solar Energy Policies and Incentives

Since 1970, Illinois has been at the forefront of renewable energy and energy efficiency initiatives. Its General Assembly was the first in the United States to pass a comprehensive Environmental Protection Act, which was signed into law by Governor Richard Ogilvie and became effective on July 1st of that year.[30]

In 2006, The Investment Tax Credit (ITC) was enacted under the Bush Administration by the Energy Policy Act of 2005.[31] The ITC is a 30 percent tax credit for individuals installing solar systems on residential property (under Section 25D of the tax code).[32] The credit has been set to expire and then extended numerous times since its founding, including in 2022 under the Inflation Reduction Act signed by President Biden, which extended the credit for 10 years at 30% of the cost of the installed equipment, which will then step down to 26% in 2033 and 22% in 2034.[33]

In 2007, The Illinois Power Agency Act (20 ILCS 3855) was passed by the State of Illinois, with the aim of establishing the Illinois Power Agency (IPA) and assigning it the responsibility of developing the Illinois Solar for All Program.[34] Also in 2007, Illinois enacted S.B. 680, which requires investor-owned utility companies and retail electric suppliers in the state to offer net metering[35], allowing consumers that generate renewable energy to sell their excess electricity back to the grid. Additionally, Illinois started offering property tax exemptions for solar panels in 2007 through the Illinois Property Tax Code, meaning that any increases in home value as a result of PV installations will not be taxed.[36]

In 2013, the city of Chicago launched the Chicago Solar Express program, which made significant changes to the process of obtaining building permits for the installation of rooftop solar systems.[37] This involved streamlining and standardizing the process, allowing small and large rooftop PV generators to access the City of Chicago Easy Permit Process. With this change, qualifying projects can now receive same-day permit approvals, reducing the wait time from 30

[30] NC State University. “Illinois Programs”. *Database of State Incentives for Renewables & Efficiency*. (2020).
[31] Solar Energy Industries Association. “Solar Investment Tax Credit (ITC)”. (2023).
[32] Solar Energy Industries Association. “Solar Investment Tax Credit (ITC)”. (2023).
[33] Solar Energy Industries Association. (2023).
[34] Reames, Tony. (2020). 3.
[35] NC State University. (2020).
[36] NC State University. (2020).
[37] NC State University. (2020).

days, and at a reduced fee of $275, down from $375.[38] This minimizes the initial cost and wait time for applying to install rooftop solar, reducing one barrier to adoption.

During the summer of 2014, the Environmental Law & Policy Center, Illinois Solar Energy Association, Vote Solar, City of Chicago, and World Wildlife Fund joined forces to provide homeowners in the Chicago area with a discounted bulk purchase option for solar panels.[39] In total, the initiative resulted in 113 new solar projects and 461 kilowatts of new solar energy capacity.[40] This program did not specifically target LMI communities.

In 2016, The Future Energy Jobs Act (Public Act 99-0906) was passed in Illinois, the most significant piece of renewable energy and climate legislation ever to pass the Illinois General Assembly.[41] The act includes a variety of programs aimed at increasing renewable energy development, including a commitment to start the Illinois Solar for All and Illinois Shines programs, which are run by the IPA. Both of these programs provide incentives for rooftop and community solar. Community solar is a model for providing access to solar energy to consumers who cannot install solar in their homes, where a large solar array is installed in a central location, and multiple households can subscribe to receive a portion of the energy generated by the array.

In 2019, as part of the FEJA, the Illinois Solar for All (ILSFA) program was launched to ensure that LMI residents have access to the benefits of rooftop solar. According to Section 1-56(b) of the IPA Act, ILSFA "provides incentives for low-income distributed generation and community solar projects, and other associated approved expenditures… to bring photovoltaics to low-income communities in this State in a manner that maximizes the development of new photovoltaic generating facilities, to create a long-term, low-income solar marketplace throughout this State."[42]

Through this program, lower-income households, defined as those whose income does not exceed 80% of the area median income, will not be required to pay upfront costs for installation, and any ongoing expenses or charges will be limited to 50% of the value of the energy generated by the solar installations[43], meaning that participants are guaranteed savings on

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[38] NC State University. (2020).
[39] City of Chicago."Chicago Solar Express." (2023). https://www.chicago.gov/content/city/en/progs/env/solar_in_chicago.html.
[40] City of Chicago. "Chicago Solar Express." (2023). https://www.chicago.gov/content/city/en/progs/env/solar_in_chicago.html.
[41] 20 ILCS 3855/1-56(b)(2).
[42] 20 ILCS 3855/1-56(b)(2).
[43] 20 ILCS 3855/1-56(b)(2).

their energy bill. An additional goal of the ILSFA program is that "a minimum of 25% of the incentives for this program be allocated to projects located within environmental justice communities", defined as communities with low-income and minority populations greater than twice the state average and are in geographic locations that potentially experience disproportionate environmental harms and risks.[44]

In 2019, Illinois Shines was also launched, which provides incentives for rooftop and community solar for individuals and businesses that do not qualify for ILSFA. This program utilizes Renewable Energy Credits (RECs), which "is a tradable credit that represents the environmental attributes of the energy produced from a renewable energy resource. One REC represents the environmental benefit (e.g., the reduction in emissions) associated with 1 MWh of energy generated by a renewable energy source."[45] Under the program, participants receive payments for 15 years in exchange for RECs generated by their solar PV system, usually about 30% of the cost of a typical system. The RECs are purchased by a utility company that has a contract with an approved vendor, which can help reduce the overall cost of installing a new PV system.

In 2021 Governor Pritzker signed the Climate and Equitable Jobs Act (Public Act 102-0662). This act vastly expands the state's renewable energy policies, including boosting funding for Illinois Shines and Illinois Solar for All. The act also establishes clean energy standards that require Illinois to generate 100% of its electricity from renewable sources like wind and solar by 2050[46]. In summary, residents in Chicago, IL have access to the following incentives and policies that could help make installing rooftop solar more affordable:

1. Illinois Solar for All: Reduces upfront and ongoing costs associated with PV installation for low-income residents and those living in environmental justice communities in Illinois.
2. Illinois Shines: Provides payments in exchange for RECs for Illinois residents who install solar panels.
3. Federal Solar Investment Tax Credit: Reduces upfront installation costs by 30% in the form of a tax credit.

[44] 20 ILCS 3855/1-56(b)(2).
[45] Illinois Shines. "About the Program". (2023). https://illinoisshines.com.
[46] Illinois Commerce Commission. "Climate and Equitable Jobs Act Implementation." (2023). https://icc.illinois.gov/programs/climate-and-equitable-jobs-act-implementation.

4. Net metering: Illinois allows PV consumers to sell their excess electricity back to the grid.

In the rest of this paper, I will analyze how these initiatives have, if at all, increased the equitable adoption of solar power in Chicago.

Analysis

This research utilized four publicly available data sources: the Google Project Sunroof dataset, the City of Chicago "hardship index," by Chicago community area, the Environmental Law & Policy Center Solar Chicago initiative dataset, and the Chicago Data Portal Building Permits dataset.

The Google Project Sunroof tool provides information for estimates of the technical solar potential of buildings in various regions nationwide. Rooftop potential is calculated using three criteria: buildings must receive "at least 75% of the maximum annual sun in the county", roofs must have a "total potential installation size of at least 2kW", and "only areas of the roof with enough space to install 4 adjacent solar panels are included."[47] The dataset used for this project measured rooftop potential by census tract in Chicago.

The City of Chicago "hardship index," for the years 2008 – 2012 utilizes data from the United States Census Bureau's American Community Survey (ACS, 5-year) to provide a selection of six socioeconomic indicators by Chicago community area. For the purposes of this project, per capita income was the primary data point used to map income levels by community area. The American Community Survey (ACS) is a survey conducted between decennial census surveys that collect data from a small sample size. The survey provides rolling estimates for 1-, 3-, and 5-year periods. The 5-year estimates are considered more dependable as they are based on larger survey samples.[48]

The Environmental Law & Policy Center Solar Chicago initiative dataset contains the location of all solar panels installed in 2014 as a result of the Solar Chicago bulk purchase initiative.

The Chicago Data Portal Building Permits dataset includes information about currently-valid building permits issued by the City of Chicago from 2006 to the present. This

[47] Project Sunroof data explorer (2019).
[48] Reames, Tony. (2020). 3.

dataset includes permits for all construction that requires a permit, not just solar panel installation. The data were filtered to include only building permits submitted for the installation of photovoltaic panels. All residents and businesses that would like to install rooftop photovoltaics must apply to the City of Chicago and ComEd for approval. This dataset was used because there is no publicly available, up-to-date information on current rooftop solar locations in Chicago. In addition, building permit data is updated daily and permits are the first step in the installation process, meaning that this dataset is very sensitive to policy changes because as soon as new incentives are put in place, people will start to submit requests for installation. From submitting the permit, it can take weeks or even months for the system to actually be installed.

Using geographic information systems (GIS) software, two Chicago community areas: Lincoln Park and New City, were mapped to compare each neighborhood's technical solar potential and income level. These neighborhoods were chosen because they have very different solar potential and income. Then, the locations of solar panels installed in Chicago through the 2014 bulk purchase program were mapped against median area income by Chicago community area. The purpose of this analysis was to determine how the initiative affected the equitable distribution of solar panels in Chicago. Next, the locations of building permits for solar panels in Chicago were mapped against median area income by Chicago community area for 2006 - 2016, 2016 - 2019, and 2019 - Present (2023). All mapping analyses were performed using QGIS version 3.28.3.

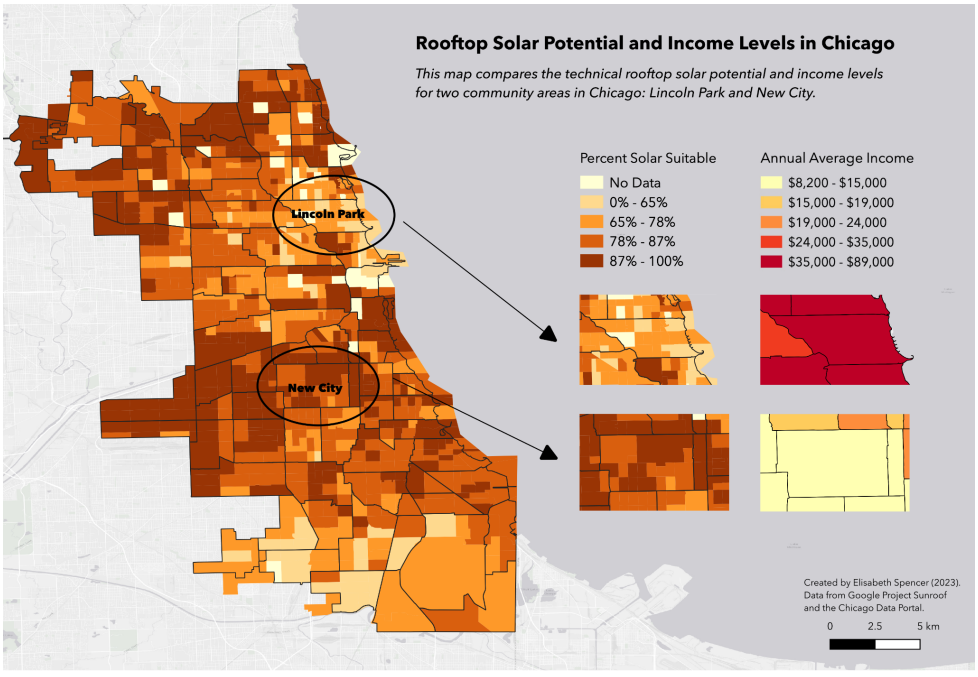

Fig.5. Income levels and solar potential in New City and Lincoln Park.

The first map (Figure 5) illustrates rooftop solar potential by census tract in Chicago. The darkest color represents the highest percentage of buildings that are solar-suitable and the lightest color represents the opposite. To demonstrate the relationship between solar suitability and income levels, two community areas were compared: Lincoln Park and New City. The lightest color for the community areas in the income map represents the lowest income levels, and the darkest is the highest. The areas with the highest percentage of buildings that are solar-suitable are clustered in the south, west, and far northern areas of the city, while the area with the lowest levels of solar potential is clustered in the wealthy downtown neighborhoods. The two neighborhoods chosen demonstrate the relationship between income and solar potential in Chicago, as Lincoln Park has high average income levels and low solar potential, while New City has lower income populations and high solar potential.

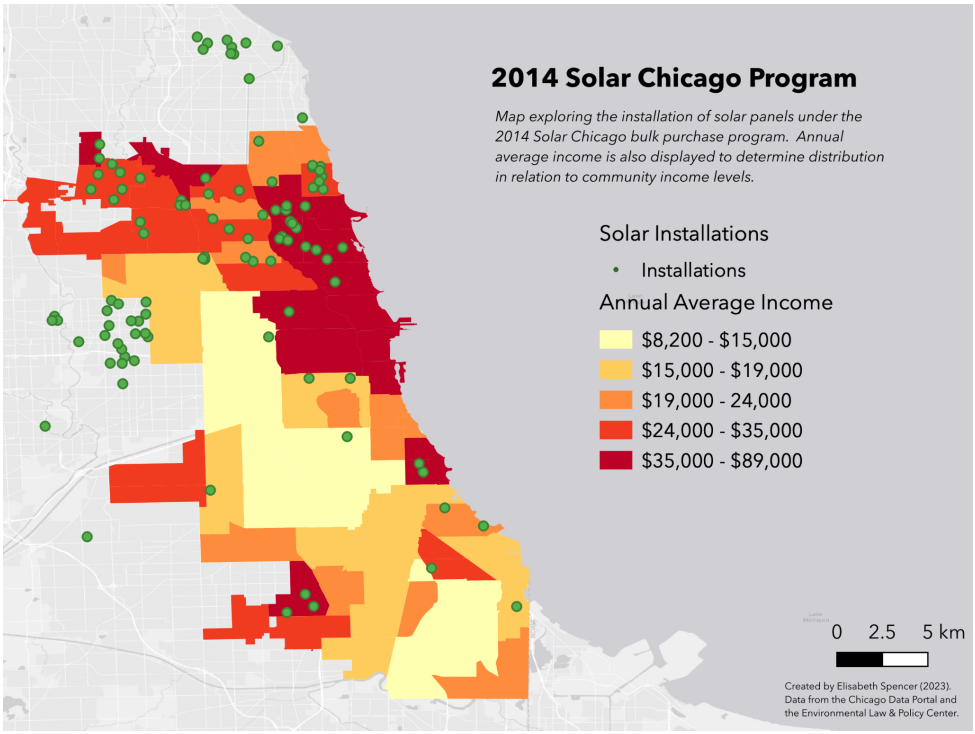

Fig.6. Distribution of solar panels installed under the 2014 Bulk Purchase Program and income levels by community area.

The second map (Figure 6) shows where rooftop solar was installed as a result of the 2014 Chicago Solar Program. This policy was not aimed at increasing equitable adoption, just overall penetration. The lighter color neighborhoods on the map represent the lowest income group, and also correspond to the least amount of solar panels installed as a result of the program. The darker colors on the map correspond to higher-income populations, and solar

installations can be seen to cluster in those areas. The impact of not explicitly targeting LMI communities is displayed through the concentration of solar panels in the higher-income northern neighborhoods in Chicago and the northern suburbs.

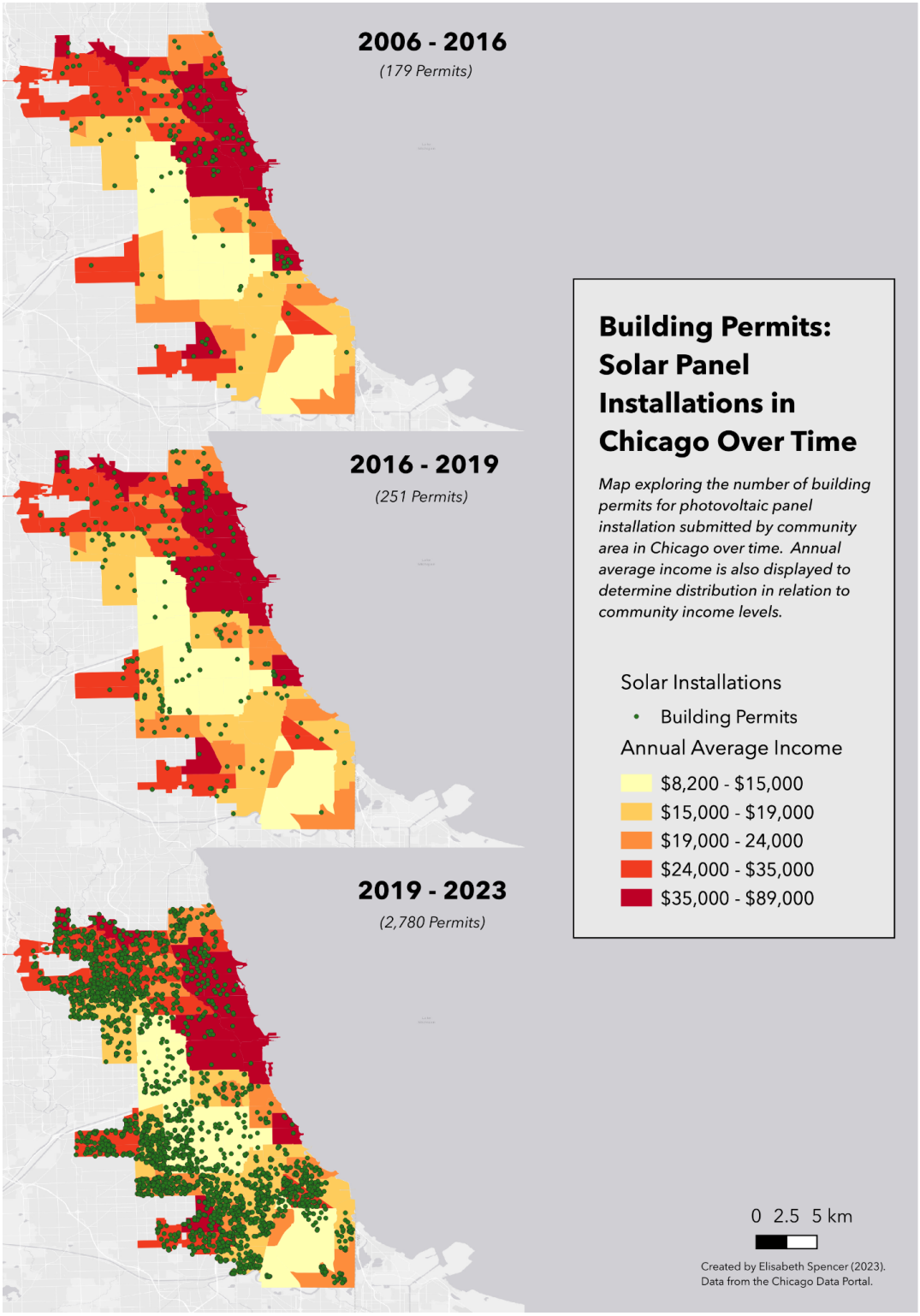

Fig. 7. The location of building permits for solar installation by community income level in Chicago.

The third map (Figure 7) shows the location of building permits submitted through the City of Chicago. Like the previous map, the lighter colors correspond to lower-income communities and the darker colors correspond to higher-income communities. The map was broken down into three different time periods to display how policies have influenced the distribution of rooftop solar at different income levels. Those three periods were chosen because in 2016 The Future Energy Jobs Act was enacted and in 2019 the Illinois Solar for All program was launched.

The top map shows installation permits from 2006 - 2016. As you can see, adoption is still very low, and installations are clustered in the northern neighborhoods with higher-income populations, and a few neighborhoods on the south and west sides with higher incomes, such as Hyde Park. Interestingly, these are also the areas with the lowest solar potential, as shown in Figure 5. At this point, no policies had been enacted in Chicago or Illinois to increase adoption in LMI populations.

The middle map displays permits submitted from 2016 - 2019. In 2016, The Future Energy Jobs Act was passed in Illinois, but Illinois Solar for all had not been enacted. At this point, there were minor policy changes aimed at increasing overall and low-income adoption, but nothing large-scale. Installations increased significantly during this three-year period, compared to the previous 10 years. Distribution began to include lower-income households and was pretty evenly distributed throughout the city.

The bottom map shows permits submitted from 2019 - February 2023. In 2019, Illinois Solar for All and Illinois Shines was enacted, aimed at increasing adoption rates overall and for LMI populations specifically. During this period, building permits that were submitted increased at an enormous rate, more than 10x in both of the previous time periods. Additionally, adoption seems to be clustered not around the higher-income northern neighborhoods, but the lower and middle-income southwest and northwest community areas. The areas with the middle colors seem to have the highest rates of penetration, and while the lowest-income areas have increased in penetration, they still have the lowest amount of installations.

Conclusion

This analysis demonstrates the importance of policy implementation that aims to increase the equitable adoption of solar panels. Figure 6, displaying the effects of the 2014 bulk purchase

policy, shows how policies do not necessarily increase penetration for LMI communities. This policy only aimed to increase overall adoption, so installation increased in higher-income populations that already have better green amenities. In Chicago, where lower-income communities also have higher solar potential (Figure 5), increasing equitable adoption is especially important in order to reach higher overall adoption.

However, when policies directly target LMI communities, they can be very effective at increasing adoption, and overall penetration rates. Figure 7 shows how policies in Illinois that decrease the upfront costs associated with solar installation have increased the number of building permits for solar panels from 179 in 2006-2016, 251 in 2016-2019, and most notably 2,780 in 2019-2023. Additionally, adoption drastically increased for LMI populations once the Illinois Solar for All program was enacted. However, penetration still remained relatively low in populations with the lowest income. This means that even with the policies and initiatives put in place, rooftop solar remains too expensive for very low-income populations.

In conclusion, rooftop solar installations have numerous benefits, including reducing energy costs, increasing home values, and decreasing greenhouse gas emissions. The cost of solar installation has decreased significantly over the past decade, and tax credits and incentives on the federal, local, and state levels make it more affordable for homeowners to install photovoltaic panels. However, the adoption of rooftop solar is not equitable, particularly for low-income and minority populations who face difficulty accessing affordable solar electricity. Illinois has launched several programs to increase solar adoption among LMI communities, including the Illinois Solar for All program, which was launched in 2019.

The mapping analysis performed in this paper demonstrates the importance of policies that aim to increase the equitable adoption of solar panels. Such policies can be effective in increasing the overall penetration rates of solar panels, particularly when targeting low-income communities directly. This is especially true in Chicago, where lower-income communities have the highest amount of solar potential. However, the mapping analysis also displays how these policies have not effectively targeted the lowest-income communities. Therefore, the city of Chicago and Illinois need to work together to implement further policies to increase adoption in these communities specifically.

Further research could explore methods to increase adoption in very low-income communities. For example, community solar has often been utilized to increase adoption among

communities that cannot afford home installation. This mapping analysis only explores rooftop solar, so any further investigation could explore the effectiveness of Illinois Solar for All and Illinois Shines in increasing equitable adoption of community solar. In addition to exploring methods to increase adoption in very low-income communities, further research could also examine the barriers that prevent these communities from accessing solar programs. These barriers may include a lack of information or awareness about the program, language barriers, or difficulties in accessing financing. By conducting further research on these topics, policymakers and stakeholders can better understand the challenges facing low-income communities in accessing solar programs and identify effective strategies to overcome these barriers. This, in turn, can help to increase the adoption of solar energy among a wider range of households and communities, leading to a more equitable and sustainable energy system.

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