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Making Solar More Affordable: Analysis of the 2021 Solarize Asheville-Buncombe County Campaign

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Abstract

Low-income households in the United States experience a disproportionately high energy burden, which is the ratio of annual energy expenditures relative to annual total household income. The energy burden of these households is expected to increase as climate change continues to impact our communities. Opportunities such as the 2021 Solarize Asheville-Buncombe's Neighbor to Neighbor (N2N) program in North Carolina are attempting to alleviate rising energy burden through solar PV installations. In addition to the group-purchasing discount available through the Solarize campaign, the program provided full and partial grants to low-to-moderate (LMI) income households in Asheville for a 3.55 kW solar array. The goals of this research project were to quantify the costs and benefits of participation in the Solarize Asheville-Buncombe campaign for households, the extent to which energy burden was alleviated, participants' attitudes toward the campaign, and why people may not have chosen to participate. A literature review of previous Solarize campaigns was completed. Cost-benefit analyses were conducted on four households: a fully granted N2N household, a partially granted N2N household who obtained financing, a non-N2N household who paid in full, and a non-N2N household who obtained financing. A survey was also conducted to evaluate participants' attitude toward the effectiveness of the campaign. This project found that the energy burden of N2N households in Asheville was not alleviated to a greater extent than those not in the program largely because the installation size for N2N households was not maximized. Additionally, a 25 year payback period yielded the greatest amount of savings for households who obtained financing. Further research is recommended to determine the best solar array size, financing package, and household characteristics for N2N households in order to maximize the program's funding in an attempt to alleviate LMI energy burden to the highest degree.

1. Introduction

From driving the economy to providing heat to our homes in the winter, energy has become imperative to our daily existence as it impacts every dimension of our lives. The energy burden, defined as the ratio of energy expenditures to overall household income, is felt in every facet of life, including housing, health, work, and education.[1] Energy-poor households are those spending more than 6% of their monthly income on energy costs.[2] Many of these households are considered to be energy insecure, which means that the household faces uncertainty in being able to make utility bill payments.[2] In the United States, energy security is more problematic for low-income households than any other socioeconomic group as they spend a higher proportion of their annual income on energy costs.

There are five factors that impact energy burden: location and geography; housing characteristics; socioeconomic situation; energy prices and policies; and behavioral factors.[2] Residents of rural communities typically have higher than average electricity and heating costs.[2] Low-income families often live in older homes with insufficient insulation and inefficient appliances, and the socioeconomic characteristics of this group inhibit them from making needed energy-efficient retrofits. Additionally, energy costs and policies include fixed components such as user fees and reconnection fees, which can further limit energy burden reduction via behavior change.

The effects of high energy burdens and energy insecurity for low-income households are that they become vulnerable to utility disconnections and eviction. A high energy burden can also result in adverse health effects such as thermal discomfort, asthma, exposure to indoor air pollutants due to a lack of air circulation, and stress-related mental health problems.[2] These health effects could be exacerbated by a lack of affordable health care, which low-income communities experience at higher rates.[2]

Additionally, climate change is increasing the frequency and severity of extreme storms, exacerbating droughts, shifting precipitation patterns, and causing more extreme heat waves.[3] These impacts disproportionately affect older homes and lower-quality housing as they are more vulnerable to weather variability. It is estimated that if the U.S. low-income housing stock was brought up to the efficiency level of the average home, 35% of their energy burden could be eliminated.[2] This could be done by weatherizing energy-inefficient homes, which decreases the amount of energy lost through efficiency upgrades in insulation and duct sealing, or by offsetting the amount of electricity consumed by producing energy from renewable technology like solar PV panels.[4] Before solar PV is installed as a means to alleviate energy burden, weatherization upgrades should be completed first in order to mitigate against unnecessary energy use.[4]

Solar PV electricity improves the efficiency of a household because it offsets energy usage, and it also produces less carbon-dioxide than power derived from fossil fuels.[4] This contributes to the well-being of the household and community, and is measured through the social cost of carbon (SC-CO_2), which economically quantifies potential long term damage done by a tonne of carbon dioxide emissions in terms of climate change effects in a given year.[5]

Solarize campaigns, which are community-based group-purchasing programs for solar energy, battery storage, and other clean energy technologies, are an effective avenue to simultaneously increase the efficiency level of low-income homes, ease their energy burden, and reduce the societal-burdened impact of climate change.[6] Additionally, Solarize campaigns can reduce the cost of going solar by lowering the associated soft costs, which include installation labor, permitting costs, financing costs, and consumer acquisition.[7] Soft costs can account for up to 50% of the total cost of the system, and can vary based on the solar array's payback period, which is the length of time required for an investment to recover its initial outlay in terms of profits or savings.[7] Therefore, a Solarize campaign helps to streamline the solar installation process by addressing three major market barriers for residential solar: cost, complexity, and customer inertia.[8]

One factor that makes solar affordable is economies of scale, which entails a proportionate cost savings in a product or service with an increase in its production.[7] The more people that sign up to install solar through the campaign, the lower the price per kW of solar PV is for all participants. A Solarize campaign reduces the complexity of going solar by initiating and facilitating competition among installers for the campaign bid, which constrains market power and drives firms toward marginal cost pricing.[7] Lastly, customer inertia is the tendency of customers to buy a product based on the perceived benefits of doing so or their trust in the product itself.[8] Therefore, having an installer already vetted and selected increases confidence about going solar, and elevates participation in the group-purchasing opportunity.[8] Solarize campaigns can also create a movement toward the green energy and climate goals of a city or county by facilitating a collective effort with the hope of a cleaner future in mind.

Solarize campaigns have been pioneered in multiple states across the country including California, Minnesota, Massachusetts, Oregon, Washington, and Wisconsin.[8] In 2013, the city of Asheville joined this group as it facilitated its first Solarize campaign. Solarize Asheville-Buncombe completed 52 installations on single-family homes in 2013.[8] Upon completion, the campaign reflected on the challenges it had faced, concluding that there were many residents and entities that were excluded. In the 2013 Solarize campaign, none of the participants were from low-income households, and the group-purchasing opportunity had not been open to businesses.

In 2016, the former Energy Innovation Task Force established the Asheville-based non-profit organization, Blue Horizons Project, to aid in making a clean energy future a reality for Buncombe County. Following this goal, Buncombe County adopted Resolution 17-12-06 in 2017, which set the goal of reaching 100% renewable energy for the entire community by 2042.[9] The city of Asheville adopted Resolution 18-279 in support of the county's goals, and established the same target date for itself.[9] With these goals in mind, Blue Horizons Project became a partner of the 2021 Solarize Asheville-Buncombe campaign. In conjunction with Summit Solar, the campaign's residential solar installer, the non-profit took on the challenge of expanding the opportunity to low-to-moderate income (LMI) residents of Asheville.[10] Blue Horizons Project closely reviewed campaigns in other cities that had a low-income component. One of these programs was Washington DC's Solar for All.

Solar for All was one of the first programs in the United States to bring solar to low-income residents specifically.[11] Solar for All's specific targets were to provide the benefits of solar energy to 100,000 low income households (defined as households at or below 80% of the Area Median Income (AMI)), and to reduce their energy bills by 50%.[9,11] The campaign implemented five 3-year phases (15 years total) to ensure that the program would be able to adapt to market changes and could effectively overcome barriers.[11] The program began 2021 celebrating the completion of its second year and is continuing to work towards its end goal of providing solar to 100,000 households in Washington D.C.[11]

Solar for All is very similar to Solarize Asheville-Buncombe's Neighbor to Neighbor (N2N) program, except N2N also extends support to moderate-income households. The N2N program provided a limited number of full and partial grants to low and moderate income households within the city of Asheville and Buncombe County.[6] Households were determined as low-income if their total income was below 70% of AMI based on their household size. Additionally, households were classified as moderate-income if their total income was between 70% and 100% of AMI.[6] The number of grants that were distributed was dependent on the amount of funding the campaign secured.

The 2021 Solarize Asheville-Buncombe campaign was the first Solarize campaign in Asheville to incorporate a low-income component into its objectives. Therefore, my research project assessed the effectiveness of the program in reaching its goals by answering the following research questions:

1. What were the costs and benefits of the Solarize Asheville-Buncombe campaign for low-to-moderate income (LMI) households?
2. How could participation in the N2N program of the Solarize Asheville-Buncombe campaign affect low-to-moderate income (LMI) households' energy burden?
3. What were the attitudes of participants in the N2N program of the Solarize Asheville-Buncombe campaign toward solar installations?
4. What were the primary reasons people did or did not complete solar installations on their homes through the Solarize Asheville-Buncombe campaign?

This research will help the Blue Horizons Project develop more inclusive and effective Solarize campaigns in the future. Moreover, this information will become increasingly important to the non-profit as well as other local entities as the city of Asheville and Buncombe County near the 2042 target date for their 100% renewable energy goal.

2. Methods

To answer the project's research questions and to provide information to the Blue Horizons Project, I conducted a literature review, an online survey, and four cost-benefit analyses on two LMI households and two non-LMI households during the summer of 2021.

At the beginning of this project's research, I familiarized myself with the 2021 Solarize Asheville-Buncombe campaign and reviewed past campaigns to understand the history of Solarize in the city of Asheville, as well as in the United States. Additional topics that were researched in this project's literature review were defining energy burden, how much larger this burden was for low-income residents comparatively, and how solar energy could be used to ease their energy burden. Solarize campaigns in other U.S. cities such as Solar for All in Washington D.C., the Solarize Philly Program in Philadelphia, PA, and Solarize Frederick County in Maryland, were reviewed as well.

This study's literature review, the Institutional Review Board (IRB) certification process, and input from the Steering Committee of the N2N program were used to create a survey. The survey's goals were to assess what participants' perceived the costs and benefits of solar to be, their attitudes toward solar PV, and how effective they felt the N2N program was in making solar more available to LMI households in Asheville. The IRB training helped to create a survey that demonstrated the three principles described in the *Belmont Report*: respect for persons, beneficence, and justice, in order to mitigate any conflicts of interest that may have risen between the survey and the campaign's participants.[12] A Likert scale, which is a five point scale that allows the individual to express how much they agree or disagree with a statement, was used to quantify multiple survey questions.[13] The survey was sent out via email using Google Forms to the 636 people who signed up for the Solarize Asheville-Buncombe campaign as of August 16, 2021.

Cost-benefit analyses, which place a monetary value on all of the factors a household experiences when installing solar on their home, were completed on four households: 1) a N2N-participating household who received a full grant, 2) a N2N-participating household who received a partial grant, 3) a non-N2N household who paid for their solar installation in cash, and 4) a non-N2N household who obtained financing.[14] The costs and consequences of installing solar were analyzed in order to draw conclusions about its relative efficiency.[14] The objective of these cost-benefit analyses was to analyze the households' reduction in energy burden as a result of their solar installation, as well as calculate their return on investment (ROI) for the array.

The potential cost and benefits of residential solar PV installations were determined and separated into two categories: 1) financial costs and benefits and 2) environmental costs and benefits. The costs and benefits were determined through the project's literature review and through a review of each household's installation quote. Each factor was monetarily quantified, and the impacts of these solar installations were assigned negative values if they were assessed as costs and positive values if they were assessed as benefits.[15]

The total amount of each household's alleviated energy burden from their solar array was determined using Equation 1. The monthly electricity cost was determined from the solar proposal provided by Summit Solar.

Equation 1. Energy Burden Calculation before Solar Installation

$$\frac{Cost\ of\ Electricity\ Per\ Month\ Before\ Solar\ Installation\ x\ 12}{Total\ Household\ Income}\ x\ 100$$

The energy burden of each household after its installation was then calculated by using Equation 2. The solar offset and new energy bill prediction was determined from Summit Solar's installation quote.

Equation 2. Energy Burden Calculation after Solar Installation

$$\frac{Cost\ of\ Electricity\ per\ Month\ After\ Solar\ Installation\ x\ 12}{Total\ Household\ Income}\ x\ 100$$

The energy burden reduction through the solar installation was then calculated using Equation 3.

Equation 3. Energy Burden Reduction from Solar Installation

$$Energy\ Burden\ Before\ Solar\ Installation\ -\ Energy\ Burden\ After\ Solar\ Installation$$

Next, net present value (NPV) tests, which calculate return on investment (ROI), were completed for each household.[16] NPV tests consider the time value of money, translating future cash flows into today's dollars.[16] For households that utilized financing, NPV tests were completed for loan payback periods of 25, 15, and 10 years. The NPV was calculated by using Equation 4, where n is the year whose cash flow is being discounted, and the discount rate was 3%.[16]

Equation 4. Net Present Value for Household Return on Investment and Energy Burden Alleviation

$$\Sigma\frac{Year\ n\ Total\ Cash\ Flow}{(1\ +\ Discount\ Rate)^{\mathrm{n}}}$$

Before NPV tests were completed, a 2.89% annual utility rate increase was applied to each household's electricity bills (Equation 5). This is the same utility rate increase that Summit Solar accounted for when calculating total savings for their customers.

Equation 5. Assumed Duke Energy Utility Rate Hike for Net Present Value Tests

$$\frac{2020\ Installation\ Bill}{(1-0.0289)^{\mathrm{n}}}$$

Additionally, annual income growth (Equation 6) was also applied to each year's energy burden calculation for all households.

Equation 6. Annual Household Income Growth Calculations

$$\frac{Average\ 2020\ Household\ Income}{(1-Average\ Income\ Strata\ Wage\ Increase\ from\ 2000-2019)^{\mathrm{n}}}$$

The SC-CO_2 for 2021 was determined by the executive branch of the government at $51 per tonne with a 3% discount rate.[17] Electricity supplied to Asheville is produced by burning natural gas.[18] When one kWh of electricity is produced from natural gas, 0.91 pounds of CO_2 is emitted.[19] Therefore, to determine the 2021 Solarize Asheville-Buncombe campaign's monetary benefit of reducing CO_2 to Buncombe County, the average amount of solar electricity produced by installations in the campaign was multiplied by the number of contracts signed as of August 16, 2021 (127 contracts). This value was then multiplied by 0.91 pounds and divided by one metric tonne (2204.62 pounds) as shown in Equation 7.

Equation 7. Household Monetary Value of Reducing its CO_2 Emissions Based on the Social Cost of Carbon

$$\frac{(average\ kWh\ electricity\ produced\ by\ Campaign\ installations\ x\ 127)\ x\ 0.91\ pounds/kWh\ of\ CO_2}{2204.62\ pounds} \times \$51$$

Following Equation 8, an NPV test was also applied to the monetary value of reducing CO_2 emissions by Solarize Asheville-Buncombe, in order to show the environmental cost savings of the campaign to Buncombe County over the 40 year lifespan of the solar PV panels.

Equation 8. Net Present Value of Household's Reduction in CO_2

$$\Sigma \frac{Monetary\ Value\ of\ the\ Campaign's\ Reduction\ in\ CO_2}{(1\ +\ Discount\ Rate)^{n}}$$

The total savings from each year of the 40 years assessed was summed for both the household's ROI and energy burden alleviation in order to highlight the total monetary benefit for each household analyzed. The total SC-CO_2 savings from the campaign was also summed to show the environmental benefit the campaign provided to Buncombe County.

3. Results

The costs and benefits of the Solarize Asheville-Buncombe campaign for LMI candidates was analyzed through a literature review and collaboration with Blue Horizons Project and Summit Solar. Four cost-benefit analyses were completed on two N2N households and two non-N2N households. Additionally, a survey was sent via Google Forms to those who signed-up for the campaign in July 2021 to evaluate campaign participants' attitudes toward solar and why those who signed up for the campaign did or did not complete a solar installation on their home. At its completion on August 16, 2021, this project's survey, sent out to 636 households, had a total of 135 participants; a response rate of 21.2%. Consent to have their responses used in this project's research was given by 100% of the survey's respondents. One question aimed specifically at N2N participants received 19 responses, indicating that 14% of survey respondents participated in the granting program.

This section presents the identified and quantified costs and benefits of installing solar PV, the results from the project's cost-benefit analyses, energy burden alleviation calculations, campaign SC-CO_2 evaluations, and survey results, as well as the findings from working with Blue Horizons Project and Solar CrowdSource on the campaign.

3.1 Cost-Benefit Analyses

The costs and benefits of installing solar for a household, regardless of socioeconomic class, were separated into two categories: financial and environmental. Table 1 highlights the general financial costs and benefits of installing residential solar.

Table 1. Financial Costs and Benefits of Residential Solar Installations

Costs	Benefits
• Upfront installation costs • Time spent finding an installer company • Cost of getting a quote from multiple residential solar installers • De-racking and re-racking fees in the case that the roof needs to be replaced during the lifespan of the PV panels • On-going payments until the the solar array is paid-off if financing is undertaken • Financing costs • Permitting costs	• Monthly electricity bill reduction after installation (net-metering benefit) • Federal investment tax credit • Increased home value

Although solar is considered a clean energy, this project did find one environmental cost associated with going solar. Table 2 reviews the environmental costs and benefits of installing solar on a residential home. The embodied energy and carbon footprint of the production of solar PV panels was not analyzed.

Table 2. Environmental Costs and Benefits of Residential Solar Installations

Costs	Benefits
• Risk of a house fire that could release small amounts of toxic chemicals if the PV panels were burned	• Reduction in greenhouse gases such as CO_2, NO_x, SO_2, and particulate matter (PM) • Reduction of air pollutant-related health risks such as asthma • Better use of land compared to fossil fuel energy production

The costs and benefits that were relevant to this project and quantifiable were identified. Table 3 lists those that were assessed in this project's cost-benefit analyses, as well as the methods used to quantify them.

Table 3. Quantifiable Costs and Benefits of Residential Solar Installations and their Evaluation Methods

Financial Costs	
Costs	**Methods**
Upfront Installation Costs	Determined by household installation quote from Summit Solar
De-racking and re-racking fees in the case that the roof needs to be replaced during the lifespan of the PV panels	Determined by Summit Solar at $150.00 per panel
On-going payments until the solar array is paid-off if financing is undertaken	Determined by household installation quote from Summit Solar

Financing Costs	Compounding interest rate, determined from Summit Solar's household installation quote, and other loan summary details were input into a loan calculator[20]
Financial Benefits	
Benefits	**Methods**
Monthly electricity bill reduction after solar installation (net-metering benefit)	Determined by household installation quote from Summit Solar
Federal Investment Tax Credit	26% Federal Investment Tax Credit that is included in Summit Solar's installation quote
Increased Home Value	Determined by household installation quote from Summit Solar
Environmental Benefits	
Benefits	**Methods**
Reduction in CO_2	Determined by using the social cost of carbon (SC-CO_2) and the average amount of kWh of electricity used by participant households

For low-income households in this program, the upfront installation costs, monthly on-going payments, and financing costs were negated as these participants received a full grant for their PV system. The partial grant-receiving (moderate-income) household's grant was used to make a down payment of $5,397 on their installation. The majority of the participants who did complete solar installations through the campaign did not make a down-payment, resulting in the non-N2N customers' upfront installation costs also being $0 (personal communication, August 19, 2021). De-racking and re-racking fees were added into the 15th year's cash flow as a negative value in each household's NPV test. This particular year was chosen because the average lifespan of a roof is 25 years, and the N2N program prioritized roofs of ten years or less.[21] Therefore, a ten year age was assumed for each household's roof as the project was not aware of non-N2N roof age. The financing costs were determined by calculating the compounding interest paid by the household on their loan through an online loan calculator.[20] Because this project was not privy to the financial details of each household's loan, a fixed interest rate was assumed for all households. N2N customers who received full grants were unable to claim the 26% Federal Investment Tax Credit (FITC) because they did not pay for the installation themselves. Additionally, the environmental benefit of reducing in CO_2 was not included in individual households' cost-benefit analyses, but was rather calculated as a sum for all participants in the campaign. This is because the household only receives a fraction of this benefit, and therefore it is more appropriate to analyze SC-CO_2 as a societal benefit for Buncombe County.

The four households that were assessed were assigned a letter identification to keep them anonymous. Table 4 represents these distinctions.

Table 4. Household Identification

Identification Letter	Household Type
A	N2N Household - Full Grant Receiving
B	N2N Household - Partial Grant Receiving and Financed
C	Non-N2N Household - Paid Cash
D	Non- N2N Household - Financed

As shown in Table 5, the NPV for all four households was positive, indicating that solar installations, regardless of participation in the N2N program, were cost-effective. Household C had the largest NPV and Household A had the smallest. It should be noted that Household A completed a 3.55 kW installation, which was the smallest array assessed. This household also consumed the least amount of electricity per month compared to the other three households. For Household B and D the 25 year payback period produced the largest NPV, meaning that the largest ROI occurred when the household completed a longer payback period.

Table 5. Results of Cost Benefit Analyses: NPV Test Totals for Four Households in the Solarize Asheville-Buncombe Campaign

Household A - Full Grant	
Payback Period (Years)	Total NPV After 40 Years
0	**$29,136**
Household B - Partial Grant and Financed: 1.99% Interest	
Payback Period (Years)	Total NPV After 40 Years
25	**$40,407**
15	**$39,987**
10	**$39,654**
Household C - Paid Cash	
Payback Period (Years)	Total NPV After 40 Years
0	**$71,356**
Household D - Financed: 1.99% Interest	
Payback Period (Years)	Total NPV After 40 Years
25	**$32,588**
15	**$30,915**
10	**$30,521**

3.2 Energy Burden

Since energy burden is the fraction of a household's total income that is used to pay electricity bills, the household's total yearly income needs to account for annual income growth when calculating total NPV. Energy bill savings also need to take into account annual utility rate increases. Annual income growth projections applied to each household were based on wage increase data from 1979 to 2019.[22] This data was averaged for low, medium, and high income stratas across all major demographics to produce an annual income growth rate that was applied to each year of the panel's 40 year lifespan.[22] This growth rate for fully-granted and partially-granted N2N households was 0.66% and 0.59%, respectively. As the majority of non-N2N households' total income fell into the high income category, a 1.2% annual income growth rate was applied. After utility rate increases and annual income growth was accounted for, the average pre-installation energy burden for fully-granted N2N participant households was 5.8%. After solar was installed, the households' energy burden was cut to an average of 3.1%. This resulted in an average decrease of 2.6%, equating to a 47% reduction in the energy burden of low-income households participating in the N2N program. Household B had a pre-installation energy burden of 3.1%, which was decreased to a post-installation energy burden of 0.7%. This resulted in a 79% reduction in the energy burden of the only partially-granted moderate-income household in the N2N program. For Solarize Asheville-Buncombe customers who did not participate in the N2N program, their average energy burden before solar was 2.7%. After solar was installed on these homes, their energy burden decreased to 1.0%, resulting in a 65% solar offset on average.

Table 6 highlights the energy burden alleviated per kW of solar PV for each household. The annual amount alleviated per kW was higher for N2N households than non-N2N households, with the average per kW of solar alleviation being $5,227 and $5,013, respectively. This shows that each kW of solar through the Solarize Asheville-Buncombe campaign went further in terms of reducing energy costs in proportion to income levels for N2N households than non-N2N households. This emphasizes the finding that N2N households have larger energy burdens than their higher income counterparts.

Table 6. Comparison of Energy Burden Alleviation per kW for N2N and non-N2N Households

N2N Households		
Participant Number	Solar Array Size	Energy Burden Alleviated per kW of Solar PV
1	7.1	$4,310
2	3.6	$5,971
3	3.6	$5,400
AVERAGE	**4.8**	**$5,227**
non-N2N Households		
Participant Number	Solar Array Size	Energy Burden Alleviated per kW of Solar PV
1	14.6	$4,352
2	14.2	$5,214
3	10.3	$5,473
4	5.7	$5,029
5	4.3	$4,999
AVERAGE	**9.8**	**$5,013**

3.3 Social Cost of Carbon ($SC\text{-}CO_2$)

The $SC\text{-}CO_2$ avoided annually by all 136 households who completed a solar installation through the 2021 Solarize Asheville-Buncombe campaign was $23,398. N2N households will avoid $1,042 worth of carbon emissions each year. As fully-granted installations were 3.55 kW, the average amount of solar energy produced annually by these arrays was 5,000 kWh. This value was assumed for all eight fully-granted installations. The N2N household who received a partial grant produced 9,509 kWh of electricity annually. Additionally, the average size of a non-N2N household's installation was 7.9 kW, which averages 9,000 kWh of produced electricity each year. This amount was assumed for all 118 non-N2N households in the $SC\text{-}CO_2$ calculation. Over the 40 year lifespan of the panels, this amounts to a total of $540,854 (adjusted for 2021 dollar value) of carbon emissions avoided by the 2021 Solarize campaign.

3.4 Survey Results

The Solarize Asheville-Buncombe Survey asked respondents about their attitude towards solar PV and the 2021 campaign, as well as what can be improved for the future. The largest fraction of respondents learned about the Solarize campaign through traditional media (26%), followed by from a family member, friend, or neighbor (24%). This reflects the first major finding of the project in that it was important to advertise the campaign outside of social media platforms and virtual events. This was especially the case when finding Black, Indigenous and other People Of Color (BIPOC) candidates, as many of these participants did not have access to the internet, nor did they have a lot of trust in Solarize Asheville-Buncombe.

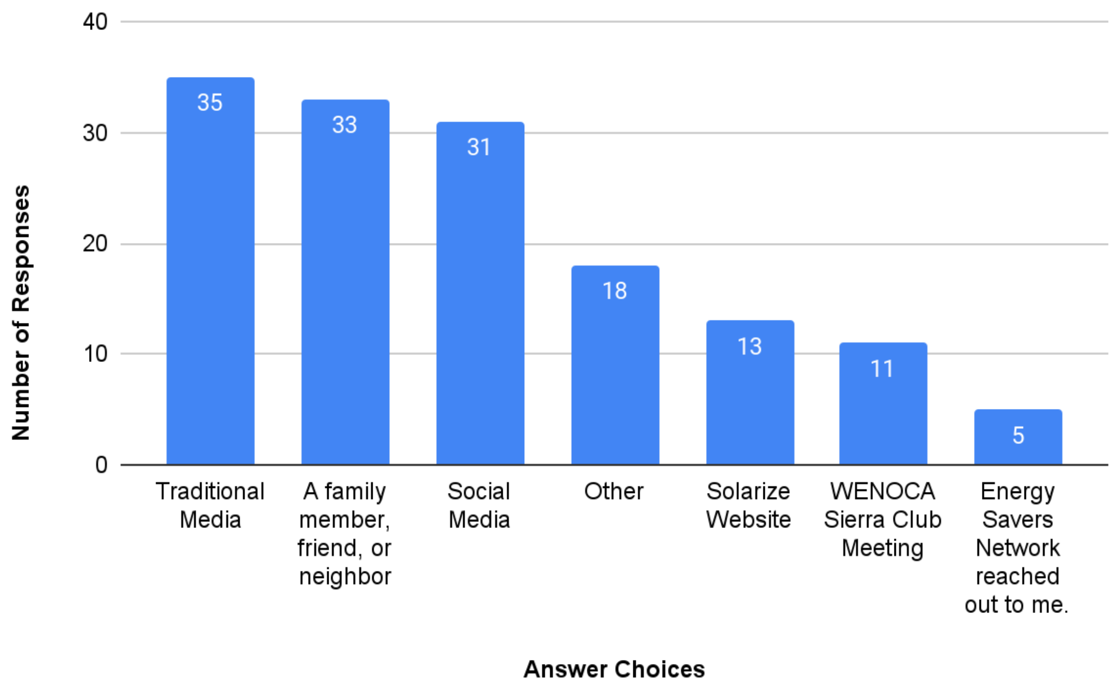

Figure 1. Effectiveness of the Solarize Asheville-Buncombe Campaign's Outreach Methods

Respondents were asked to identify the top three reasons why they might install solar on their home based on the answer choices provided. There was also a write-in option available. As shown in Figure 2, respondents indicated that the most common reasons for going solar were 1) energy independence and climate resiliency; 2) renewable technology that is free of harmful CO_2 emissions; and 3) to meet personal sustainability goals.

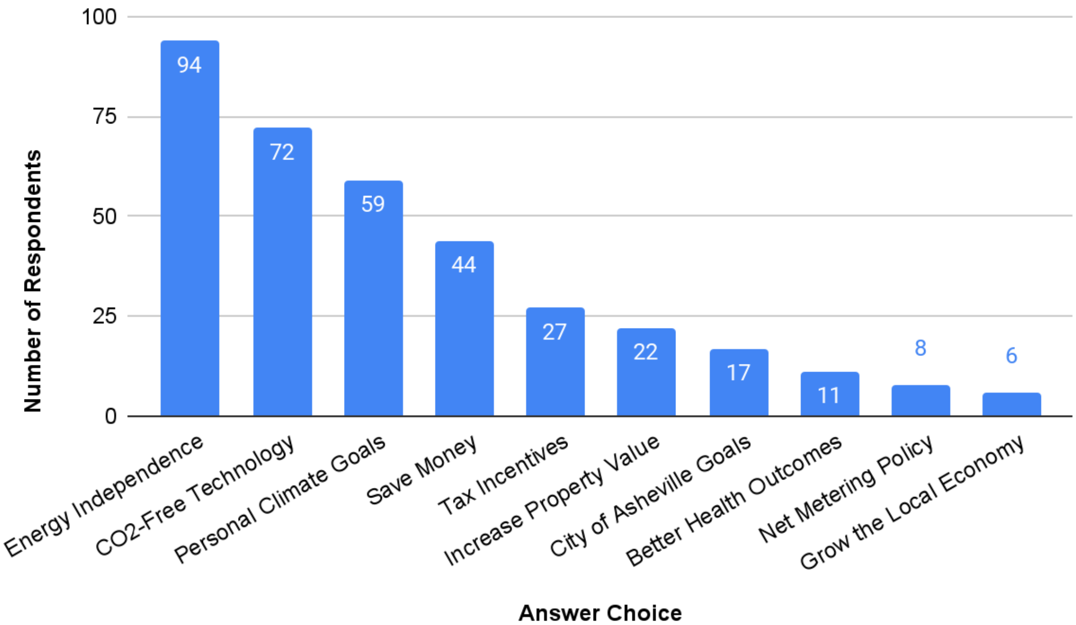

Figure 2. Reasons Participants Might Install Solar on Their Home

Figure 3 reflects the results from the question, *"If you did NOT complete the process of installing a solar array through Solarize Asheville-Buncombe, why not?"*. Participants were asked to either select all of the predetermined answer choices that applied to them, or to write in an answer if it was not already included. The most common reason selected by respondents was that they found it too expensive (27%). This was followed by the fact that they did not trust Solarize Asheville-Buncombe to provide the highest quality product and best pricing possible (15%), and that the solar potential of their home was too low (15%). The majority of respondents chose to write in a response to why they chose not to complete a solar installation (28%). The three most common written-in reasons included: 1) miscommunication between Summit Solar and campaign participants around the Duke Solar Rebate; 2) confusion around the merger of Titan Solar and Summit Solar; and 3) participants preferred to use a local solar installer.

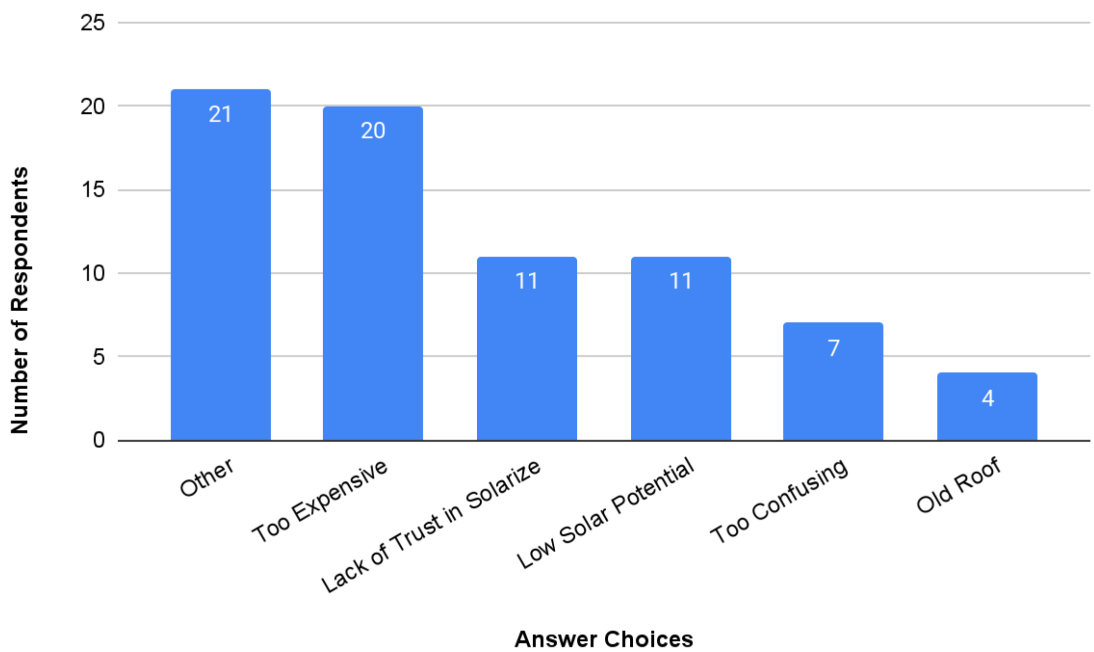

Figure 3. Reasons for Incomplete Solar Installation Processes in the Campaign

The largest percentage of respondents indicated in the survey that their total annual income was more than $100,000. This demonstrates that the majority of participants in the campaign were not considered LMI households. Figure 4 emphasizes another finding that the Blue Horizons Project made during the Solarize Asheville-Buncombe Campaign: in order to extend the opportunity of solar to LMI and BIPOC households in Buncombe County, the non-profit had to shift from using their funding for 50% partial grants and 50% full grant installations to 20% partial grants and 80% full grant installations. According to Beatrice Nathan of Blue Horizons Project, this was because only 2.9% of the homeowners in Asheville are of LMI communities, and the program has difficulty finding moderate income households who could afford and prioritize a partially-granted solar installation (personal communication, June 15, 2021).

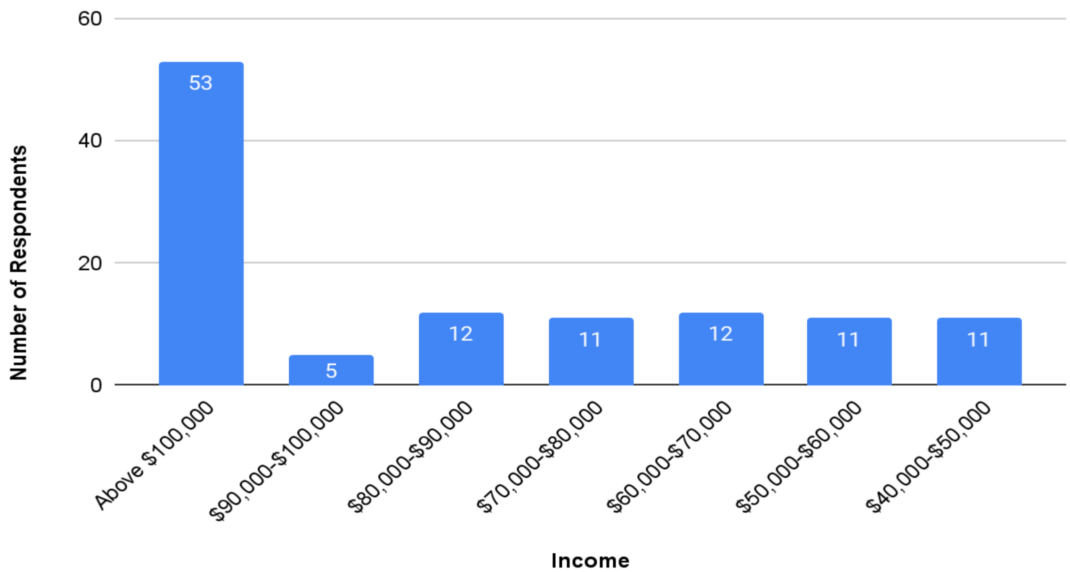

Figure 4. Campaign Participants' Total Household Income in 2020

In response to the survey question that assessed the perceived fairness of grant distributions through the N2N program, 47% of respondents indicated that they were neutral to the level of fairness displayed in the grant funding process (Figure 5). When asked to explain their selection to this question, respondents emphasized another finding of this project: many people do not have an accurate idea about the solar appropriateness of their home or the appropriateness of their income for receiving a full or partial grant. Many people signed up for the N2N program, not knowing that there were specific factors required for receiving a grant. There was also a misunderstanding about what qualified as total income in the beginning stages of the granting process. During the recruitment process, the non-profit found that they needed to further screen candidates to prevent false hope that a household would qualify for a full grant. These additional qualifications included having less than $50,000 in savings, a roof age of 15 years or less, and having a solar potential greater than 0.6. Additionally, Blue Horizons and SolarCrowd Source decided to include an additional question concerning the race of candidates as the program's goal is to specifically reach BIPOC communities. The resulting mistrust was reflected in the survey as one participant described the N2N process as a "waste of time" because the grant funding requirements were not clearly explained online and changed during the recruitment process.

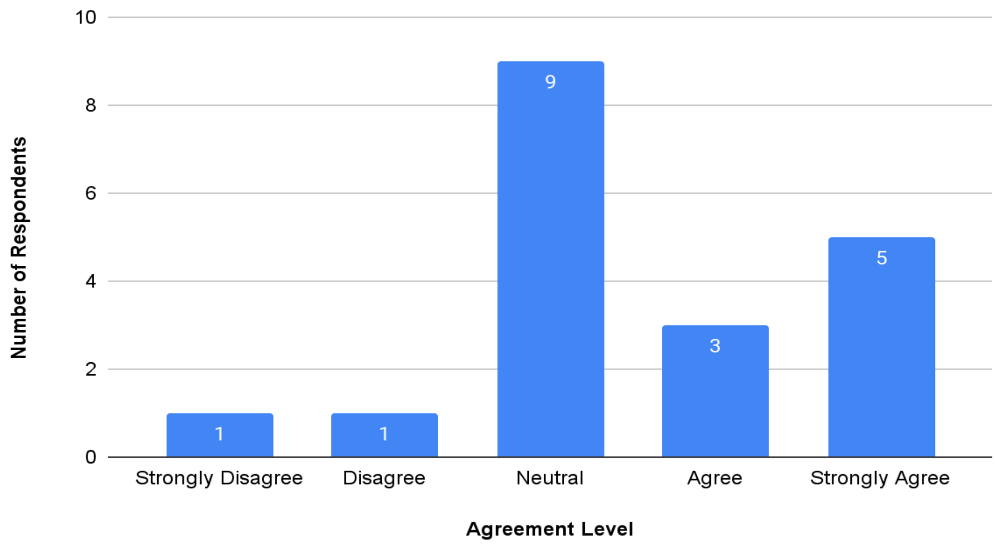

Figure 5. Participant-Identified Level of Fairness Displayed in the N2N Program Granting Process

In response to the question, *"What do you think could be improved for future Solarize Campaigns?"*, 30% of participants indicated that there needs to be more funding available for fully or partially-granted solar installations in the future (Figure 6). This was followed by improved tiered pricing and financing options for LMI households (30%). "Better communication between the solar provider and customers in terms of financing options" was selected by 19% of respondents further highlighting the need for more clarity between Blue Horizons Project, Summit Solar, and the campaign's participants during the recruitment process.

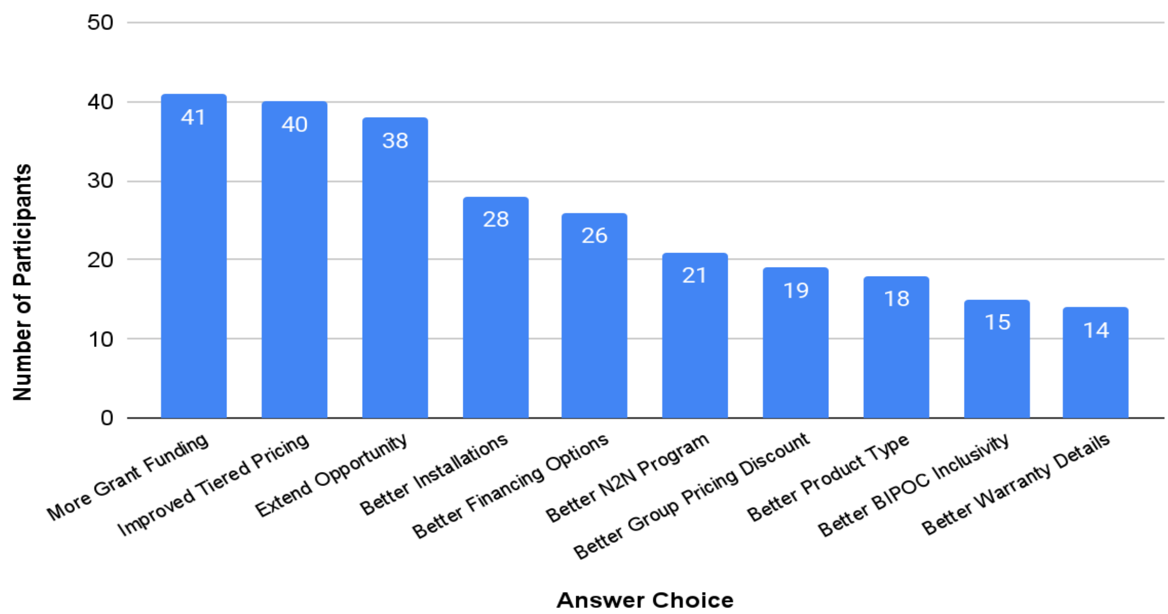

Figure 6. Recommendations for Improvements in Future Solarize Asheville-Buncombe Campaigns

4. Discussion

Through my literature review, I found that low-income households have the highest energy burden when being compared to those of moderate and higher incomes.[1] Washington D.C.'s Solar for All campaign, which Solarize Asheville-Buncombe drew from, is a successful example of how Solarize campaigns can reduce this burden for low-income households. This project's research found that the benefits of installing solar PV through the 2021 Solarize Asheville-Buncombe campaign outweigh the costs, deeming installations cost-effective over the 40 year life-span of the solar PV panels. Therefore, Solarize campaigns can be used as an avenue to equalize the disproportionate energy burden felt by low-income households in the United States. Furthermore, a low-income component is vital to extending the opportunity of solar to all residents of a community as many respondents to this project's survey who did not complete an installation through Solarize Asheville-Buncombe reported that they still found the process too expensive, despite the discounted group-purchasing tiered pricing structure.

4.1 Energy Burden Assessment

The average American low-income household has an energy burden of 7.2%.[1] Participants of the N2N program had a lower energy burden of 5.8%. However, since this average is very close to the 6% minimum bound for a household to be considered energy burdened, it can be inferred that the majority of low-income households in Asheville are within this designation.[1] The level of burden that these households experience can vary based on location and geography, housing characteristics, socioeconomic situation, energy prices and policies, and behavioral factors of the households.[2]

The average energy burden alleviated through the N2N program was 47%, which is lower than the alleviation level of Washington D.C.'s Solar for All campaign.[11] Solar for All reduced low-income households' energy burden by 50% so far through its 15 year implementation timeline.[11] Solar for All brought solar energy to low-income households in Washington D.C. through community rooftop solar PV installations, where multiple households utilize power from one array through a subscription system.[11] Community solar was not a possibility for Solarize Asheville-Buncombe as third party solar arrays are illegal in North Carolina.[23] Because Duke Energy is a regulated monopoly, it is the only company allowed to provide energy to North Carolinian residents.[23] House Bill 589, passed in 2017, requires Duke Energy to provide 40 MW of community solar to the state.[23] As of 2021, Duke Energy's Shared Solar program has not built any community solar projects.[23] This is largely because the parameters around Shared Solar are restrictive, making it difficult to get any projects off the ground. Additionally, because community solar is not an option in the Asheville area without the cooperation of Duke Energy, the N2N program and the greater Solarize Asheville-Buncombe campaign did not accommodate households who do not own their own home, nor did it include mobile homes as their roof structures are typically unable to support rooftop solar PV. Mobile homes tend to have much higher energy burdens as they are less energy efficient compared to other popular housing types. These residences are typically occupied by low-income families, and therefore are most at risk of large energy expenses.[2] Therefore, because rooftop solar PV is not feasible for everyone, community solar projects would allow Solarize Asheville-Buncombe to reach a larger population.

Furthermore, the energy burden alleviation for N2N participants was not greater than the alleviation of non-N2N participants. These results in effect did not reinforce the expectations of this project's literature review that the energy burden alleviation from a solar installation should be greater for LMI households than households from other socioeconomic groups.[2] However, my results indicated that N2N installations did alleviate a larger proportion of low-income households' energy burden per kW. This suggests that N2N-granted solar installations could have resulted in a higher energy burden alleviation compared to non-N2N installations if the granted arrays had been bigger than 3.55 kW. The N2N program attempted to maximize energy savings while also extending this opportunity to the greatest number of households possible. Therefore, because of limited funds for the program, N2N installations were smaller than those of non-N2N households, which equated to less solar energy production and subsequently less energy burden relief for LMI residents. At the end of the campaign, the N2N program moved from fully granting 3.55 kW arrays to 3.7 kW arrays due to a standard panel upgrade by Summit Solar. Even though the increase in array size is negligible, the larger array reduced the gap between N2N and non-N2N alleviation levels. Additionally, while the N2N program was funded through contributions from Buncombe County, local businesses, and private individuals, Washington D.C.'s Solar for All program was funded through compliance fees paid by electricity suppliers.[11] This allowed Solar for All to not only generate more funds for their program compared to the N2N program, but to also have a steadier flow of granting money available.

4.2 Cost-Benefit Analyses and NPV Tests

Compared to other Solarize campaigns completed around the United States, such as the Solarize Philly Program, Solarize Asheville-Buncombe participants will enjoy a greater return on their investment.[24] After 25 years, which is the warranty term of the panels, Philadelphia residents' average NPV was $11,941 after utility rate increases were taken into account.[24] The average NPV for Solarize-Asheville Buncombe participants after 25 years would be $43,372, including both the N2N households and the non-N2N households sampled in this project. The large difference in ROI between Solarize Asheville-Buncombe participants and participants in Philadelphia may be because the Solarize Philly Program accounted for a 0.4% annual utility rate hike, which is lower than the 2.89% hike applied in this project.[24] Furthermore, the Solarize Philly Program did not include a LMI component, emphasizing that the ROI for Asheville residents compared to residents in Philadelphia is even greater.

The NPV tests for all households analyzed were positive, indicating that installing solar, regardless of socioeconomic status, was cost-effective for a residential participant. These results implied multiple inferences about the cost-effectiveness of solar for participants of the Solarize Asheville-Buncombe campaign. First, the campaign reduced multiple soft costs for households that are usually incurred during solar installations.[7] An example of a soft cost that the campaign managed was permitting costs, which are typically high for residential projects. This value was already included in Summit Solar's installation quotes, so each household's specific cost was unable to be discerned. It should be noted that the average permitting cost to install a residential solar array in Buncombe County is $192, although this cost increases if the household has to resubmit an application, make changes to an application, or if the household resides in a historic district or in a flood plain (Hart, personal communication, July 1, 2021).

Second, the NPV of the fully-granted N2N household was lower than that of the other participating households. This can be explained by the fact that the solar array did not increase the value of the N2N home as much as it did the other homes, that the fully-granted solar array was smaller, and that the household consumed less electricity per month on average. Third, the NPV of the partially-granted N2N household was greater than that of the financed non-N2N household, even though both payback periods were 25 years and the partially-granted installation was two kW larger, making it more expensive. This highlights how the aid of a partial grant helped the N2N household receive a return on their investment faster.

Additionally, the results of this project showed that the NPV for households who obtained financing were higher with a payback period of 25 years than a payback period of 15 or 10 years. This may have occurred because the 1.99% interest rate of the loans was not high enough to yield a negative cash flow consistently over the 25 year payback periods. Thus, the low interest rate coupled with the lower principal payments each month created a higher ROI over the 25 year payback period compared to the 15 or 10 year terms. However, further research needs to be completed as this finding is not supported by previous studies, which highlight a shorter payback period providing a great ROI.[24]

4.3 Social Cost of Carbon

Different organizations and institutions use different SC-CO_2 rates, which can contribute to variation in the true cost of carbon within the United States. The National Academies of Sciences, Engineering, and Medicine set the 2021 social cost of carbon at $42 with a 3% discount rate for 2020.[25] For the federal government, the social cost of carbon and the preferred discount rate are set by the executive branch, and, therefore, it is important to note that these values are subject to change with the political climate. The 2021 SC-CO_2 rate of $51 was higher than the rate that was set by the previous administration, which ranged from $1 to $6 per metric tonne of carbon (in 2021 dollars).[25] Because of the political nature of this estimate, the true cost of carbon emissions to society could be underestimated.

4.4 Importance of Clear Communication

Future Solarize Asheville-Buncombe campaigns should take more advantage of in-person information meetings, if possible, as other campaigns around the United States have had great success with this method of outreach. Solarize Frederick County hosted workshops and installation demonstrations, which elevated interested households' understanding of the Solarize process as well as the operation of rooftop solar PV.[26] Solarize Frederick County used in-person, hands-on workshops to avoid inaccurate expectations of the benefits and costs of going solar.[26] Confusion around the 2021 Solarize Asheville-Buncombe campaign, which was reflected in this project's survey, was due to miscommunication between stakeholders, inappropriate advertising and misleading infographics, and qualification changes made during the course of the recruitment period – all of which were exacerbated by the COVID-19 pandemic. The campaign was only able to host virtual town hall and informational meetings, which could have contributed to the confusion and misguided expectations of participants.

While Solarize Frederick County was completed in 2013 and did not face the challenges of a global pandemic, it does provide an interesting solution to the mistrust between N2N candidates and the program's operators.[26] Solarize Frederick County employed a neighborhood-specific approach to its outreach and marketing efforts.[26] The campaign was able to spread awareness to a larger population on a more specific and personal scale. Additionally, because Solarize Frederick County made the effort to tailor outreach and marketing efforts towards the characteristics of specific neighborhoods, word of mouth transmission of the campaign was elevated as people had a clearer idea of the process and benefits of the opportunity.[26] Solarize Frederick County also began with a concrete outreach plan and recruitment process that greatly aided in its success. As the 2021 campaign is the first to incorporate a LMI component, Blue Horizons Project underwent a major learning curve. The non-profit found that they needed to further screen candidates on the front end of the recruitment process to prevent false hope that a household would qualify for a full-grant. Blue Horizons and Solar CrowdSource also decided to include an additional question around the race of candidates as the program's goal was to reach BIPOC communities specifically. This miscommunication likely could have been avoided with distinct qualifications, straightforward infographics, and a complete understanding of the associated challenges by the N2N program from the beginning.

Another major takeaway from the project's survey was that many candidates who signed up for Solarize Asheville-Buncombe but failed to complete a solar installation through the campaign reported that their main reason for doing so was because they found it too expensive. Respondents indicated that they felt like the best improvement to future Solarize campaigns would be to include more grant funding opportunities and better tiered pricing. Research has shown that Solarize campaigns correlate with a statistically significant increase in the annual income of participants compared to other creative financing options for solar energy targeted at lower-income households such as the Property Assessed Clean Energy (PACE) program and third party ownership of solar arrays.[27] Therefore, Asheville and Buncombe County should attempt to implement different programs in order to best bring solar energy to this demographic. The combination of programs is largely determined on the socioeconomic makeup of the area, the state laws regarding solar energy production, and the utility costs of these households. It should also be noted that in order for these programs to work, each household's financial background and ability to make monthly payments needs to be properly assessed in order to avoid these programs from becoming regressive.[28] This would occur if monthly payments interfere with the household's economic stability.[28] Additionally, weatherization practices should be undertaken first in order to ensure the maximum energy efficiency of the home.[28] This is especially the case for solar inefficient homes such as those with roofs that cannot support rooftop solar PV.

5. Conclusion

Despite the mixed findings in this study, Solarize campaigns should not be abandoned or perceived as ineffective in providing solar energy to low-income households as a way to lower their energy burden and alleviate the impacts of climate change. Research completed by the IMS Global Learning Consortium showed that the prices of solar panels dropped by 55% between 2009 and 2012.[29] The price of solar PV is expected to continue to decrease in the future, and therefore should become more accessible to households regardless of whether installations are completed through a group-purchasing program like Solarize Asheville-Buncombe. Therefore, participation in Solarize campaigns in the future could be more cost-effective and accessible to people from a wider range of socioeconomic backgrounds.[29]

Moreover, future Solarize campaigns should include more opportunities for programs like the N2N program that specifically target LMI households. The N2N program was successful in alleviating the energy burden of those that are most disadvantaged in Buncombe County, but it was unable to do this to a greater degree than higher income participants, largely because of the smaller PV array sizes of N2N installations. Therefore, it can be concluded that larger solar PV installations through N2N will maximize the program's impact on LMI energy burden. Findings from this project also provide valuable information to Solarize campaigns in the United States as precise and meaningful communication around the qualifications, expectations, and challenges of these programs is paramount. Avoiding misconceptions around Solarize campaigns targeted at LMI communities can prevent mistrust and usher greater levels of participation. Therefore, the 2021 Solarize Asheville-Buncombe campaign has been successful in its goals of creating a better energy future for its community, but a greater emphasis on communication between future campaigns and their participants as well as greater funding for the N2N program must occur in order for the city of Asheville and Buncombe County's clean energy goals to become a reality.

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