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Shady solar: understanding barriers and facilitators to residential solar adoption for low- and moderate-income homeowners in New York City

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Low- and moderate-income (LMI) households face substantial barriers in accessing solar energy despite incentives at the local, state, and federal levels. Notwithstanding the rapid deployment of resources, there is still much to understand and address from a program design and implementation perspective to effectively realize an equitable energy transition. This qualitative study, which draws on interviews with policymakers, implementers, and LMI homeowners, provides novel insights into barriers and facilitators surrounding the inclusive adoption of solar energy. Our findings underscore the substantial differences and frequent misalignments in perspectives among these stakeholders. We find that both implementers and LMI homeowners encounter economic and administrative burdens, though the specific ways these factors hinder solar adoption differ between the groups. We leverage the viewpoints and experiences of policymakers, implementers, and LMI homeowners to guide evidence-based recommendations to overcome the many hurdles that actively impede equitable and inclusive solar adoption.

KEYWORDS

equitable solar, energy justice, energy insecurity, energy transition, low-and moderate-income homeowners

1 Introduction

Access to clean and affordable energy is vital for a community's health, economic growth, and financial stability. Low-income households and communities of color face high energy costs and inefficient housing and have limited access to renewable energy (Hernández, 2016; Drehobl et al., 2020; Baker, 2021). These challenges are exacerbated by the climate crisis which disproportionately affects marginalized populations compounding the risks of exclusion from the clean energy transition (Kolzenburg, 2022). Furthermore, disadvantaged communities are most at risk of facing acute and chronic energy insecurity (Hernández, 2016; Jessel et al., 2019). Thus, racial and socioeconomic inequities must be meaningfully addressed and prioritized in policymaking as efforts to decarbonize the energy system proliferate.

TABLE 1 Key Residential Rooftop Solar Incentives with Implications for LMI groups.

Key residential rooftop solar incentives	Description of incentive program	LMI implications
Federal Investment Tax Credit	- Tax incentive accruing to owner of solar array	- Low tax liability may limit LMI ability to maximize incentive
	- Up to 26% of eligible costs in 2022*	- Tax credit goes to 3rd party owner under PPA/Lease
State Residential Tax Credit	- Tax incentive accruing to homeowner	- Low tax liability may limit LMI ability to maximize incentive
	- Up to 25% of eligible costs	- Incentive is reduced under 3rd party ownership arrangements
NY-Sun Incentives	- Reduces up-front installation cost	- Relies on solar developer to pass on costs
	- Incentive provided to developer based on system size	- Limited use of LMI incentive to date in NYC
	- Higher incentives for households <80% AMI	
Net Metering	- Systems installed before 2022 received net metering	- Early adopters, who are likely to be higher income, received greater financial benefit than late adopters (Ardani)
	- Systems installed from 2022 onwards receive net metering, but must pay a flat monthly fee	
City Property Tax Abatement	- Tax incentive accruing to homeowner	- Low tax liability may limit LMI ability to maximize incentive
	- Up to 20% of eligible costs	

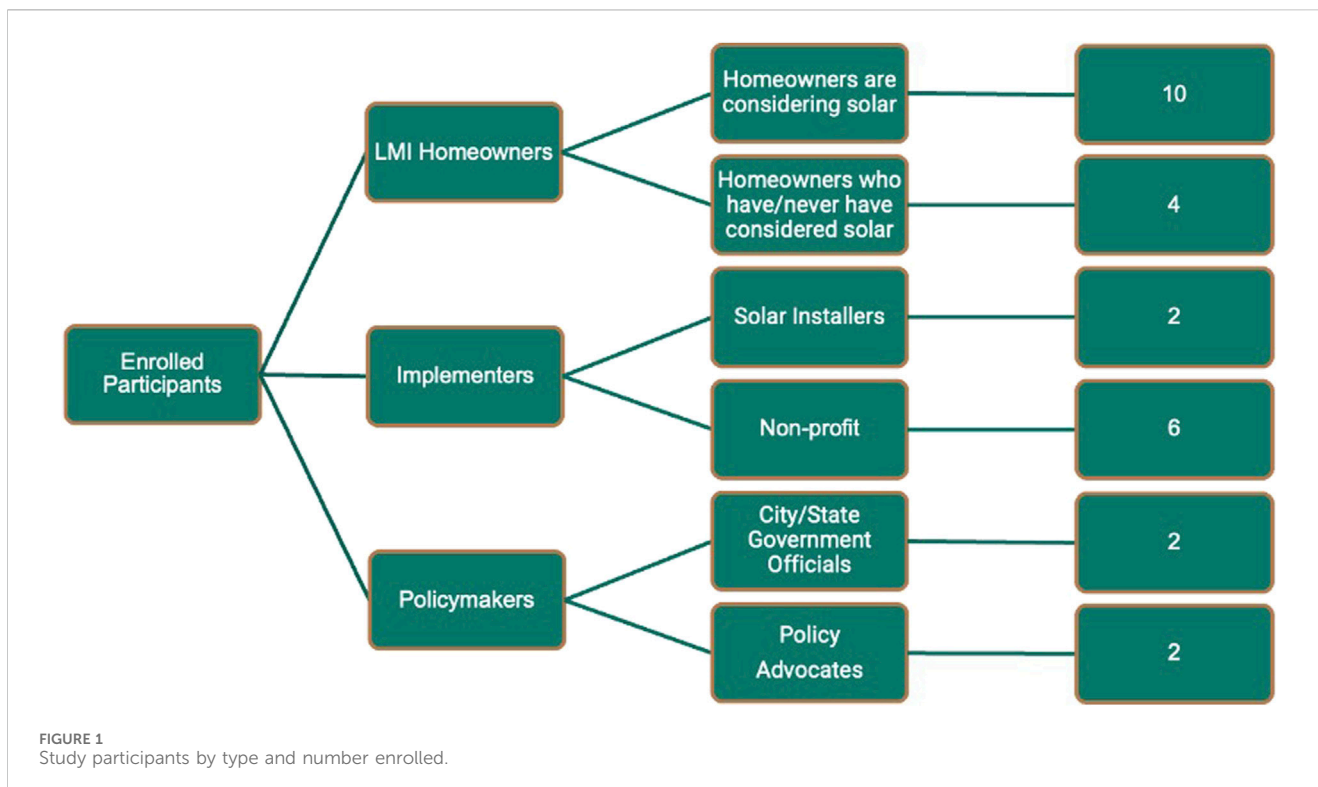
Solar photovoltaics are an important technology in the transition away from fossil fuels (Ringsmuth et al., 2016). As solar becomes more affordable and necessary to decarbonize the energy system (Hamilton et al., 2018), research has begun to explore residential solar adoption among LMI communities (Baker et al., 2018; Brown et al., 2020; Srivastava, 2019). Studies exploring the motivation for homeowners to adopt solar have identified several reasons: 1) financial savings from solar (Wolkse, 2020; Bao et al., 2019; Moezzi et al., 2017; National Renewable Energy Laboratory; Rai, 2016), 2) environmental benefits of solar (Schelly and Letzelter, 2020), and 3) peer influence in homeowners' decision-making process (Kesari et al., 2021).

LMI households may see the greatest financial benefit from solar given their higher relative energy cost burden, although the technology remains inaccessible to many despite available incentives and declining costs of solar (Lu, 2016; Sun et al., 2022). To date, federal- and state-level solar incentives are geared towards homeowners rather than renters, which limits the ability of renters to participate in the clean energy economy (Heeter, 2021). Moreover, since homeownership has historically been out of reach for low-income individuals and people of color, many disadvantaged groups are also unable to embrace solar energy at comparable rates. This is due to their status as renters or the limited financial resources in the form of income or wealth, that preclude costly upgrades (Hughes and Podolefsky, 2015). Another barrier LMI residents face in adopting solar is access to financing, as solar experts acknowledge banks' rigid and burdensome approval processes for loans to fund solar projects (Davuluri, 2019). LMI Incentives may alleviate some financing barriers but are not always sufficient to spur equitable access to capital or overcome barriers for renters or multiple unit housing dwellers regardless of housing tenure status.

Although research on solar adoption is advancing, it is important to develop knowledge for geographic locations that are implementing ambitious solar policies. One such example is New York City (NYC) and New York State (NYS) which have introduced various initiatives to accelerate uptake of rooftop solar in models

that have since inspired federal programs. For residential rooftop solar, NYS enables net metering, third-party ownership models such as power purchase agreements and leases as well as community solar subscriptions, while NYC provides property tax abatements (see Table 1 for a list of solar-related policies at the city and state level in New York). Of note, in 2019, NYS passed the Climate Leadership and Community Protection Act (CLCPA), putting the state on the path to installing 6 GW of solar and achieving 100% clean electricity by 2040 as well as carbon neutrality by 2050. The law uniquely targets at least 40% of benefits of decarbonization for "disadvantaged communities," (The New York State Senate, 2019) defined as communities that "bear environmental and socioeconomic burdens as well as legacies of racial and ethnic discrimination." This framework has since been adopted at the federal level through the Justice 40 Initiative as part of the Infrastructure Investment and Jobs act of 2021 and the Inflation Reduction Act of 2023. Despite NYS and NYC having active solar interests entrenched in policy, it is unclear that the benefits of solar energy are effectively reaching disadvantaged groups. Moreover, lessons learned in this context can be instructive as the federal level policies are currently underway.

ElectrifyNYC was created in 2020 as part of city and state commitments to realize more equitable outcomes in solar adoption. A co-designed initiative, led by Kinetic Communities Consulting Corporation, Neighborhood Housing Services of Queens and Staten Island, and the NYC Mayor's Office of Climate and Environmental Justice, was established as a free service to help homeowners benefit from emission reductions via heat pump, solar, and energy efficiency upgrades. The present study—co-developed by a leading researcher on energy equity at Columbia University (DH) in partnership with the aforementioned organizations and funded by the NYS Energy Research and Development Authority (NYSERDA)—aimed to better understand barriers and facilitators to solar adoption for LMI homeowners in NYC and providing a social science lens and important context in the implementation phase to then inform policy recommendations for an equitable and inclusive path towards a just energy transition within the domain of rooftop solar.



2 Methods

This two-part study used a community-engaged approach to explore attitudes, opportunities, facilitators, and barriers regarding solar adoption among LMI homeowners in NYC. The first part of the project involved collaboration between the ElectrifyNYC program partners listed above and the academic research team to co-design the study objectives and data collection procedures, co-create in-depth interview guides and collaborate on the analysis and write-up of results. Three interview guides were drafted, one for each of the targeted stakeholder groups: LMI homeowners (<120% area median income, with at least a portion <80% area median income to correspond with existing solar incentives), policymakers, and implementers (see Figure 1). An intake form was used to screen homeowners and establish eligibility based on income and interest in or adoption of rooftop solar. The implementer and policymaker participants were recruited based on their organizational affiliations and titles as identified via online searches and through professional networks.

The subsequent part of the study involved audio-recorded interviews conducted virtually with members of each group. We interviewed homeowners with varied engagement in solar adoption, including those who successfully installed rooftop solar, some who started the process of installing solar, and others who were unaware and had not pursued solar installation options. Among program implementers, we interviewed representatives from nonprofit, community-based organizations and for-profit solar installation companies. Lastly, we interviewed policy advocates and NYC and NYS government officials charged with shaping and designing relevant policies. The research team recruited participants via community partner referrals, social media, and field-based

recruitment. In total, 26 participants were interviewed for this study, 14 of which were homeowners, eight were implementers and four were policymakers (see Figure 1).

Two members of the team analyzed (AB, CD) interview transcripts using Nvivo, a qualitative software analysis package that assists in the management of transcripts and facilitates coding and analysis of text-based data. The first phase of analysis involved “open coding” in which all transcripts were coded to descriptively assess the data. The researchers then developed a codebook that outlined and defined each code and systematically applied codes from the codebook to all interview transcripts in a second pass. This process resulted in the identification of emergent themes that characterized and explained the nature of solar adoption among participants in the various stakeholder groups. The second phase entailed “axial coding” in which codes were thematically grouped and patterns in the data were critically assessed to explore and elucidate barriers and facilitators as summarized in Table 2. To solar adoption across the groups and experiences navigating local resources for solar adoption among LMI households in NYC.

3 Findings

In this section we describe our main study findings which reflect how participants in each stakeholder group described key barriers and facilitators to effective solar adoption for LMI groups. Table 2 summarizes high level results from the thematic analysis by participant types including homeowners, implementers and policymakers. This section goes into more depth on these results starting with barriers, of which there were more and then facilitators.

TABLE 2 Summary of findings by each participant type.

Participant type	Barriers	Facilitators
<i>LMI Homeowners</i>	• High upfront costs	• Growing energy burden
	• Legacy of distrust	• Vigilant conservation
	• Administrative burden	
<i>Implementers</i>	1) Misaligned policy design	• Motivated consumers
	2) Administrative burden	• Deep-rooted community knowledge and trust
	3) Information gaps	
<i>Policymakers</i>	1) Insufficient tax appetite	• External pressure
	2) Monopoly of private interests	

3.1 Barriers

Among homeowners, high upfront costs, economic and administrative burdens, and distrust of energy companies and utility service providers served as impediments to solar adoption. Meanwhile, the policy design process, information gaps, and economic and administrative burdens faced by implementers served as hindrances to serving more households. Policymakers observed that budgetary challenges along with decisions and processes that protect the interests of powerful actors were critical deterrents at higher levels. What follows are additional details of the barriers to solar adoption across each domain.

3.1.1 Homeowners

3.1.1.1 High upfront costs

Many homeowners were motivated by potential savings and considered solar to be a viable option in helping to reduce monthly energy bills. However, homeowners who were either considering solar or had never considered solar for their homes repeatedly noted the challenges associated with high upfront cost of installation. LMI households have less disposable income than wealthier households, so the upfront cost of solar was seen as a major barrier.

Some homeowners took several steps to adopt solar for their homes but were ultimately deterred by the unattractive prospects of entering into what was often perceived of as murky financial agreements for a third-party-owned system with lower savings potential. The hesitancy to enter financial agreements were often related to unfavorable terms including the total and monthly costs, the length of the agreements, the ownership status of the array including stipulations around what happened to the solar unit upon selling the property. Distrust of the energy industry was another factor as furthered examined in the next section.

3.1.1.2 Legacies of distrust

Energy service companies (ESCOs) have been shown to engage in predatory practices and take advantage of limited energy literacy and populations desirous of energy cost savings (Gardner and Stern, 2008; DeWaters and Powers, 2011). ESCOs have disproportionately targeted communities of color, people with limited English language proficiency, and the elderly (Patterson, 2021). Among the LMI homeowners we interviewed, most did not distinguish between solar company and energy supply ESCOs, likely due to similar

sales tactics and messaging and the overarching connection to energy sourcing and distribution. Many households noted they were unwilling to consider solar because they did not trust energy companies as they had either heard stories about ESCOs' predatory practices or been personally scammed.

Another factor contributing to issues of distrust was the experience many homeowners had with their energy bills. For most homeowners, their closest interaction with energy revolved around their utility providers and the monthly bills they receive from them. When homeowners experienced unexpected increases in energy bills without any explanation from their providers, they felt isolated and unprotected and this inspired a fundamental distrust of profit-motivated energy suppliers. Moreover, the combination of affordability, accountability, and transparency issues perpetuated feelings of distrust in the energy industry, which extended to solar companies as well especially because they did not fully believe the claims of savings or back-up power access. LMI householders tended to be guarded in their transactions with solar companies or organizations seeking to facilitate solar installations due to this lack of trust.

3.1.1.3 Economic and administrative burden

LMI homeowners were increasingly concerned with the rising cost of living in NYC, including energy-related expenses. Many homeowners were burdened with trying to reduce their energy costs and employed vigilant conservation strategies (Simes et al., 2023), which entailed pursuing various energy use reduction approaches and energy assistance avenues to get by including enrolling in payment plans with energy providers. Access to solar incentives as well as resources to support weatherization and energy efficiency services was often impeded by the complexity and amount of cognitive and administrative resources needed to take advantage of certain programs designed to benefit LMI households. Seeking information and resources from the government was often described as a conundrum and hassle rather than a helpful endeavor.

Participants noted that understanding the incentives available to reduce upfront solar costs took a significant amount of research and time. Homeowners repeatedly described struggling to find correct and up-to-date information to make informed decisions regarding solar and energy services. Moreover, when interacting with solar companies, participant felt that they were not always made aware of which incentives they were eligible for and how to access the discounts or other pertinent benefits. One homeowner described the arduous

TABLE 3 Barriers facing homeowners, implementers, and policymakers. There are direct quotes from interviews conducted with policymakers, households, and implementers. These quotes are used to understand what themes across these three categories of interviewees appear in relation to barriers and opportunities for solar adoption amongst LMI households.

Participant	Theme	Exemplary quotes
Homeowners	High Upfront Cost	<i>“At the end of my meetings and calls with the three solar companies that I talked to; I was not ready to sign on for any of it because if you lease or buy the wages tied into everything, it just did not make any sense as a homeowner to subjugate myself.”</i>
	Legacies of distrust	<i>“ConEd is your energy supplier, which seems like a bit of a monopoly because I do not have an option. I had a bill in January for \$1,400. That was my heating for that month, but usually my bill is around \$700 to \$800. In the winter months it doubled. And I did write to my local representative, I was like ‘When are we going to stop the monopoly of these electric companies? And when are we going to make them not for profit?’ Because that’s the issue. It has shareholders, and they want to make money but at the expense of the consumers.”</i>
	Economic and Administrative Burden	<i>“Did you ever go online to look for federal funding and grant money stuff like that? It is literally going to this page to go to this page to go to another page to try to look for the information, not finding a backtrack, and you still can’t find it. And if you find it, it’s like one sentence.”</i> <i>“I interviewed six to eight solar companies before I made my decision to go into solar. So, I really wanted the information to see if it was consistent across the board from all these solar companies I interviewed.”</i>
Implementers	Misaligned policy design	<i>“As long as the tax credit incentives are structured in a way where you need to have taxable income to take advantage of solar, the incentives are not as advantageous to low-income households.”</i>
		<i>“So, when you’re starting to do and develop initiatives the focus is on energy efficiency and clean energy technology. It’s always a very top-down approach, let’s just, you know, fly in, drop this and disappear, which is very disruptive with our communities.”</i>
		<i>“If you’re telling me you have a home with a blue tarp on its roof in Staten Island, you’re gonna tell them I’m gonna pay 80% of your solar panels with a broken roof. What’s the point? It happens all the time where people are selling technology to disadvantaged communities, and then they’re stuck with this financial burden of this technology with a base load that’s off the charts, and then they can’t afford it. And then they wind up going through foreclosure and displacement and their project is counted as we hit the solar installation goal. There’s a very big disconnect within the market.”</i>
Economic and Administrative Burden	<i>“You’re trying to get communities that have been historically disincentivized to go from -30 to 100. While it’s easier to get folks that are at 40 to get to 100. And that cost from going from -30 to 40 is going to be significantly higher because there’s decades of disinvestment than just slapping a panel on a huge farm.”</i> <i>I think the most challenging aspect is to stay on top of the need and the demand for the services and provide counseling and advice in a consistent and high-quality way while serving everybody that reaches out to us. . .</i>	
Information gap	<i>“I think there’s this misconception of people not knowing about solar. But once we start kind of diving into it, they’ve seen it, they know what it did. One of the things that everyone across the board always thinks is that solar has a battery attached to it. And so that’s where we’ll come in and say you’re right, except that we need to have the battery sold separately. I feel like they’re pretty knowledgeable.”</i>	
Policymakers	Insufficient tax appetite among LMI	<i>“There’s a state tax credit for solar system that’s currently at \$5,000 and you can carry it over for 5 years. But for something like that you would need to have tax liability for that to even benefit low to moderate income folks . . . many will not have the necessary tax liability to even take advantage of that.”</i>
	Monopoly of private interests	<i>“Fast forward to this [solar] roadmap, NYSERDA made the calculations based on we’re hoping that solar companies, when they plug in, and they’re doing business, they can get like a 6%–7.5% rate of return on the work. That was the primary analysis for understanding how this went. And then after that was done, they’re like, well how can we then make sure that some percentage of the capacity for solar is—quote unquote, and I’m just using the heaviest air quotes I could possibly get—to serve low-income disadvantaged community members to satisfy this law.”</i> <i>“So basically, the way that NYSERDA is calculating these benefits is that they are claiming that over 40% of investments will occur in disadvantaged communities. What we argue is just because an investment is made within the geographic bounds of a disadvantaged community does not mean that those community members are actually benefiting. And so, to be transparent about this is to acknowledge that the majority of benefits go to the solar developers and banks. And they think it’s sufficient that 20% or more low-income households will receive a 10% bill discount. They’re not looking at any kind of ownership or wealth generation or community wealth building opportunities for folks, it’s straight up these 10% bill discounts at a time when people have utility arrears. The average person is behind by over \$2,000. So, what is a 10% discount going to do when you’re not using that much energy? Your bill is maybe \$50, maybe \$100 a month, so \$5 or \$10 off is not going to get you out of this \$2,000 hole that you have. And it’s going to lead to displacement.”</i>

process of vetting information from multiple companies when considering solar options. This participant recounted spending hours interviewing various solar companies to gather accurate information engaging in the process alone and without proper guidance on what to look for in a company and how to make the best decision.

Ultimately, this participant adopted solar, but the effort was substantial and taxing. For others, the complexity, lack of trust and

insufficient resources served as barriers to solar adoption even as they were otherwise interested and embracing of the idea.

3.1.2 Implementers

3.1.2.1 Misaligned policy design

Many program implementers and solar companies also described frustration with inadequate incentives available to LMI

households and customers. As one implementer noted the tax incentive structure is not well suited to LMI groups who may lack the tax basis by which to fully benefit from existing approaches. Beyond flaws in incentive design and eligibility requirements, implementers articulated that there were deeper shortcomings in the approach for program design and implementation. Many implementers described programs with stringent targets that did not incorporate and promote community engagement and language accessibility which can lead to poorer participation outcomes among immigrant groups and deepen the community's distrust of government agencies and energy providers. As quoted in [Table 3](#), one implementer highlighted the disruptive nature of clean energy programs that have minimal community engagement built into the program design and roll-out phases. This implementer shared that the focus for many of New York's clean energy programs is scaling electrification, which limits the ability to implement solutions customized to each community's needs and preferences, which may include weatherization, energy literacy or energy efficiency upgrades—essentially the building blocks to solar.

From the perspective of community-based organizations (CBOs), current policies and programs for increasing solar adoption do not adequately support, incentivize, and protect the interests of LMI groups. An important CBO-Implementer perspective was that as part of their mission, CBOs were invested in their community's economic and infrastructural resilience and this vantage point rendered them as experts on the needs and demands of their respective communities. These participants believed that community-held expertise and trusted brokerage must be valued, in more ways than one, i.e., through financial support, policy design incentivizing community engagement, entrusting program design and implementation to the community, and building education programs to close the persistent knowledge gap. In failing to adequately uplift and support CBOs in their crucial role, another layer of disempowerment emerged, resulting in missed opportunities to catalyze change across multiple levels.

Another disconnect in the process that served as a deterrent to solar adoption as described by CBO implementers pertained to financial mechanisms and specifically to credit score requirements which served to limit access to financing. Accordingly, many LMI households must access financing in order to afford solar installations. However, low-income households and households of color tend to have lower credit scores in comparison to white, higher-income households ([Rice and Swesnik, 2013](#)).

Specifically, Black and Latinx credit scores are 52% and 29% lower, respectively, than those of white individuals ([New York State Department of Public Service, 2024](#)). With lower credit scores and at times credit-invisibility, low-income households and households of color were unable to establish creditworthiness to access favorable financing which, in turn, locked them out of adopting solar.

3.1.2.2 Economic and administrative burden

There was acute awareness amongst some implementers that the process for transitioning to solar is especially complicated for historically disadvantaged communities.

Although deep and sustained community engagement by CBOs is effective to grow solar adoption, this can require extensive and costly operational and personnel costs that are not often fully accounted for or compensated through grants and contracts. Some CBO implementers described comprehensive community engagement approaches and activities, such as hosting webinars and training sessions to help homeowners learn about solar and its potential benefits, as well as convening community meetings and participating in local fairs to raise awareness among constituents. Implementers created and provided materials in various languages and provided direct “high-touch” services such as helping households find suitable and trustworthy contractors and identifying available financial options in order to fully usher would-be adopters through the process. Some CBOs leveraged workforce development funding to make headway in deinstitutionalizing technical knowledge about renewable energy through programs such as the Solar Pioneers Program. This program trained local youth from the Brownsville neighborhood about “the importance, benefits and practical elements of solar power, prepared them for possible interactions with homeowners and taught them how to assess homes for damage,” ([Leonhardt, 2018](#)) in order to support the Solarize Brownsville campaign. This strategy allowed organizations to train community members and ensure that the community retains technical knowledge in an approachable manner. However, this approach also entailed serving the community in a more comprehensive and integrated manner, which often required additional time and institutional resources to execute effectively.

Implementers play an important role in households' access to information, energy systems knowledge, installation, and other contractual services. Those that enacted hands-on approaches, such as in-person engagements, tabling at events, webinars, translation of technical knowledge, active communication with interested parties added several layers of administrative elements and cost to their program implementation efforts. Moreover, because existing policies and programs mostly fail to adequately invest in community engagement, these implementers were also financially burdened by carrying out uncompensated activities aimed at building relationships and trust. Such grassroots work demands significant resources to guide community members through the various stages of the process and served as a pivotal approach in bridging the gaps in solar adoption. Yet, this unrecognized and unremunerated effort depleted institutional resources and placed additional strain on employees who were dedicated to the cause but were also stretched thin due to limited organizational capacity and the extensive nature of the tasks.

3.1.2.3 Information gap

Some solar installation companies perceived customers as having limited awareness of solar and available incentives. An interesting finding shared by CBO implementers was pushing back on the misconception in the industry about the knowledge consumers have about solar. A CBO implementer noted that in communities with large immigrant populations, many residents had been exposed to solar and other renewable technologies in their native countries. This does not mean that customers fully comprehended the technical and policy details of solar energy.

However, when implementers underestimate consumer knowledge, perspectives, and experiences with solar, it impedes their ability to build trust, develop relationships, and meaningfully bridge the gap in policy or technology-specific knowledge. It also disregards the efforts people made to research and educate themselves as much as possible, despite the lack of transparency and readily available information.

3.1.3 Policymakers

3.1.3.1 Insufficient tax appetite among LMI

Targeted policy and government programs are most effective in improving household efficiency, reducing energy burdens, and deploying renewables and storage equitably (Frank and Nowak, 2016; Reames, 2016). From the perspective of policymakers, the key barrier for LMI homeowners was the lack of policy designed to alleviate financial burdens. Federal, state, and city residential tax incentives are not direct pay meaning that the amount of incentive a household can claim is limited by its annual tax liability. LMI households typically have a lower tax “appetite” and thus limited ability to make full use of these incentives than people with higher tax burdens. Thus, the fundamental design of the incentive is misaligned with the financial realities of LMI groups, a perspective that was also mentioned by implementers.

In terms of the financial arrangements that then flowed from this impractical incentive structure, participants noted that LMI homeowners have the option to lease or enter into power purchase agreements, wherein the solar company monetizes the federal tax credit to help finance installation of the system. While these options help broaden who can participate in the energy transition, the credit score requirements can still bar LMI households who generally have lower credit scores or are credit-invisible. Further, the financial benefits of third-party ownership are lower than direct ownership. Therefore, because the ideal financial scenarios do not apply to LMI groups, they are often relegated to a second-tier financing structures and suboptimal, and unattractive, solar adoption strategies.

3.1.3.2 Monopoly of private interests

Interviewed policy advocates pointed to power imbalances in the state policymaking process as a factor contributing to untargeted policies. They pointed out the policymaking process not only lacks inclusiveness towards environmental justice advocates and their recommendations, but is also monopolized by the priority of ensuring profitability of the private solar developers and utilities. This criticism extends to the apportionment of funds and intended beneficiaries. The emphasis on profits and maintaining the hegemony of private developers means that disadvantaged communities receive limited advantages even as state law mandates an allocation of 35%–40% of benefits to disadvantaged groups.

The policy implications described in the featured quote in Table 3, are particular to one solar policy program but highlight the disconnect between policymaking and implementation and how privileging the private sector’s profitability may diminish LMI households’ ability to participate in the clean energy transition or achieve household energy security when securing profits through the

policymaking engine trumps energy access and affordability writ large.

3.2 Facilitators

Although there were fewer facilitators than barriers, better understanding of these levers can help scale and refine efforts to increase solar adoption. Table 4 includes direct quotes from the participant stakeholders across a number of domains. Homeowners highlighted the role that solar could play in reducing energy cost burdens and shared their desire to conserve energy and engage in environmental stewardship through solar and other energy efficiency upgrades. Implementers noted that LMI customers were highly motivated to adopt solar either because they care about the environment or because they are seeking to save money on utilities or some combination thereof, which is very consistent with how homeowners described themselves. Implementers also found solar to be an outlet for empowering the community and seeing it as a way to develop the workforce and link community members to the clean energy economy. This avenue for social and economic improvement and empowerment via solar was a way of addressing fundamental needs in the community in a holistic way. Meanwhile, policymakers focused on external pressure and the need to be responsive to community concerns as articulated by advocacy groups and needing to uphold the terms of fair and equitable engagement from the inside.

3.2.1 Homeowners

3.2.1.1 Growing energy burden

For homeowners, motivation to adopt solar tended to be influenced by their energy bills along with a general concern for environmental sustainability. In some cases, homeowners were motivated by savings as well as a desire for consistency in their energy bills. Several participants expressed frustration with unexpected increases in their energy bills. For many homeowners, the COVID-19 pandemic and inflation markedly increased their energy bills. Some participants noted that they had difficulty paying their bills and were participating in payment plans offered by their utility companies. Therefore, the existing and growing energy burden faced by LMI homeowners contributed to interest in solar. One homeowner described a high energy burden and payment arrangement as a rationale for seeking relief through solar. Others were led to consider alternative options to circumvent existing monopolies and the inability to hold utility service providers more accountable from an affordability perspective.

3.2.1.2 Energy conservation and environmental stewardship

Participants’ perceptions of solar adoption were enhanced by their desire to reduce energy burden and engage in environmental stewardship. Most participants described elaborate methods they used to conserve energy, primarily to reduce energy bills including forgoing comfort in the heating and cooling seasons, as is consistent with previous research (Simes et al., 2023). Furthermore, participants also shared that they motivated to incorporate energy efficiency improvements for their homes and appliances to reduce energy consumption and solar would be an extension of those investments. They were also enthusiastic about adopting modern technology that had a larger environmental benefit as well.

TABLE 4 Facilitators of solar adoption for homeowners, implementers, and policymakers. There are direct quotes from interviews conducted with policymakers, households, and implementers. These quotes are used to understand what themes across these three categories of interviewees appear in relation to barriers and opportunities for solar adoption amongst LMI households.

Participant	Theme	Exemplary quotes
Homeowners	Desire to reduce energy burden	<i>"I have not paid the bill, I can't pay. I just put down as much as possible. And now we've worked out a payment plan. The contract would take me into 2030 if I pay, I do not know, \$600 or \$700 a month, so it's the usage. Plus, I think it's \$50 a month towards that bill. But it's beyond someone of my means."</i>
	Environmental stewardship and energy conservation	<i>"The last time we bought a refrigerator was about 5 months ago. That's the energy saver on that one. So whatever else we're adjusting in terms of appliances or light, we always have an eye for what is the best one to save energy. So that's the natural consciousness when we buy appliances or when we buy lights."</i>
Implementers	Motivated customers	<i>"There are kind of those two groups. They're the environmentally conscious ones who are combating climate change. And then there are the ones that are looking for cost savings. And there's some overlap too."</i>
	Holistic approaches to addressing community needs and interests	<i>"The ability to camouflage climate justice with workforce development is imperative to get people to understand how much money they can save with solar . . . As you go into low-income communities, sustainability is synonymous with sufficient or enough. For us to increase solar adoption, you must include workforce development so basic needs are met."</i>
Policy makers	External pressure	<i>"I spent months meeting with NYSERDA, other community advocates, putting together comments, trying to figure out not just what are the criticisms that we can make but what are the things that we can advocate for? And then to see none of our recommendations be meaningfully included? It is demoralizing . . . we do not want to participate if our recommendations are not going to be actually considered and actually implemented because then it's not worth our time."</i>

3.2.2 Implementers

3.2.2.1 Motivated consumers

According to interviewed implementers, many households are indeed interested in solar although the motivating factors may differ. One participant described the importance of tailoring services to meet the growing demand for solar having grouped interested parties by whether they were primarily motivated by environmental or economic reasons, which was consistent with the motivations expressed by LMI homeowners themselves.

The high demand for information and services related to solar indicates widespread proliferation of knowledge and interest in renewable energy among NYC residents, suggesting that existing barriers are policy-related and systemic and not related to lack of interest of LMI households *per se*.

3.2.2.2 Holistic approaches to addressing community needs and interests

Some community-based implementers pointed out that their biggest strength was that they knew how to engage with their neighborhood and use networks of trust and shared histories to effectively communicate the relevance of solar and reap multiple benefits of solar programs. For example, a CBO implementer noted they were cognizant of the need for economic growth in their community, so in developing a program to address energy burden and promote solar adoption they prioritized the workforce development component. Through this program, they trained community members in solar installation, customer service, and sales. The implementers were aware that their community did not trust energy companies, so they worked to rebuild trust and ensure that their community was not preyed upon by ESCOs. Community-based implementers viewed investing time and resources into relationships as well as flexibility in program implementation to address other compounding disparities as a

critical components of equitable solar adoption and realizing clean energy's restorative justice potential.

3.2.3 Policymakers

3.2.3.1 External pressure

Advocacy plays a crucial role in holding government agencies accountable and ensuring equitable policies are implemented. New York-based advocacy organizations were keen on ensuring that the demands of their communities are heard during policymaking processes. Organizations involved in policy implementation also sometimes pressure state agencies to deliver on climate and equity goals through various stakeholder and community engagement processes. Both advocacy organizations and state agencies believed external pressure significantly promoted equitable solar adoption. In fact, pressure from advocacy organizations helped the state pass CLCPA, which provides leverage for advocacy organizations to hold state and city agencies accountable. Furthermore, it adds pressure on NYS and NYC to fulfill the mandates of the CLCPA as there is increasing pressure to prioritize equity. Hence, it serves as a crucial and practical tool in ensuring that the policies' ambitions are truly achieved. Nevertheless, advocacy organizations pointed out that while there is expectation for engagement during stakeholder processes, there is a lack of accountability from the agency to respond and communicate how comments are integrated into policy and programmatic designs. Therefore, the process can seem extractive and ineffective.

4 Discussion

The primary takeaway from this study is that LMI homeowners, implementers and policymakers and advocates care about solar access but have different motivations and face unique obstacles to more inclusive solar adoption. Our results indicate that factors such as increased energy costs and environmental stewardship serve

as facilitators for homeowners and help drive demand for services from implementers. However, high upfront costs and misalignment of financial tools were noted as barriers across stakeholders. Administrative burdens plague both end-users and implementers while information gaps, distrust in the energy industry and catering to profit interests fuel skepticism towards policymakers and the process overall. Community-based implementation and external pressure are positive influences in the effort to support equitable solar adoption and are key components of refining current policy and programmatic offerings.

Perspectives from study participants point to significant opportunities for equitable policy design and implementation to ensure solar adoption is more accessible to LMI homeowners in NYC and beyond. Interest in solar adoption is growing, creating an ideal climate for state and local leaders to take action to address systemic policy barriers. Below are recommendations that stem from the evidence presented above to realize potential for increased solar adoption among LMI households.

4.1 Invest in community participation and engagement among trusted parties

CBOs dedicated to their community's economic and infrastructural resilience are experts on the needs and demands of their respective communities. Many participants in our study highlighted the importance of community participation, buy-in, and engagement to ensure trust between solar implementers and households, technical knowledge transfer, and opportunity for proliferation in solar adoption. Based on this finding, it is recommended that.

- 1) Trusted community partners lead program implementation in marginalized communities,
- 2) Greater investments are made to support meaningful community engagement, and
- 3) Long-term funding is provided to community partners with flexible timelines and programmatic parameters.

These recommendations are grounded in ensuring that community-held expertise is valued and that trusted partners are incentivized to lead this work. The salience of flexible funding for developing community partnerships and active engagement is paramount to doing this work meaningfully and effectively. To overcome administrative and financial limitations, it is necessary to focus on CBO capacity building including providing strategic guidance on how to incorporate costs associated with community engagement into project budgets. There must be abundant resources available so that partners can provide sufficient and responsive assistance to advance solar adoption. Moreover, it is critical to evaluate the effectiveness of various strategies to reach LMI households and establish best practices for the field.

4.2 Reform tax incentive structures to reduce costs

The recent passage of the Inflation Reduction Act into law stands to reform federal tax incentive structures and provide a

direct-pay option to non-profits and municipalities. LMI homeowners also benefit from provisions initially included in the Build Back Better Act, which provide a direct pay option. However, the Inflation Reduction Act presents new opportunities for non-profit and public sector actors to serve LMI households in ways that address trust barriers and increase financial benefits compared to for-profit organizations. Yet our findings show that many LMI households are unable to benefit from solar incentives directly given limited tax burden. To make tax credits accessible to LMI homeowners, we recommend the addition of a direct pay option and other financing mechanisms including grants or on-bill financing specifically for LMI households to complement existing local, state and federal incentives programs.

4.3 Increase energy literacy and building trust in energy systems

There are persistent trust and knowledge gaps related to the energy system among US residents. Most households have cursory understanding and exposure to energy services through their monthly bills but are often only aware of how much they owe and not how the usage is calculated. This leaves many households at a disadvantage and higher risk of exploitation. To build energy literacy and increase trust in the energy system, there must be statewide initiatives to close the energy literacy and trust gaps at all levels including K-12 and adult education. Moreover, educational programs must be bi-directional.

Our results indicate that implementers underestimate what consumers know, yet research has demonstrated that LMI households are especially vigilant in their energy consumption patterns (Simes et al., 2023). Therefore, programs should be co-developed with consumers to ensure that their knowledge is valued and validated. Support from state-funded programs designed to grow the clean energy workforce and grow public understanding of the energy system could be an effective tool in realizing these educational efforts.

4.4 Exempt LMI households from consumer benefit contribution

New York State's net metering policy for solar installations after 2022 includes a consumer benefit contribution charge, a "monthly fixed charge used to fund energy efficiency programs, solar programs, and low-income discount programs." All new residential solar adopters post-2022 will experience an increase in their monthly bills (Phelps, 2021). This may be a concern for LMI households that are not early adopters of solar technologies. One main motivating factor for solar adoption by LMI households is to reduce their energy burden. While net metering policies can allow households to benefit from solar in multiple ways, adding a charge without considering the existing economic and energy burdens experienced by LMI households is regressive. Therefore, we recommend that LMI consumers be exempt from the consumer benefit contribution charge. Exempt households should then be prioritized for participation in energy efficiency and solar access

programs to overcome under-enrollment challenges that plague energy assistance benefits (Simes et al., 2023; Andrea et al., 2023).

4.5 Expand community solar

NYC is unique in that the majority of its residents are renters. However, most of the current programs and policies developed by the state—and federally as well—are designed for homeowners.

Community solar projects have emerged as an alternative to residential rooftop solar to address issues related to split incentives, housing quality, and high upfront costs. Community solar programs allow residents of all types to adopt solar without the requirement to install solar panels on their own roofs by subscribing to a group of solar panels that are connected to the local grid. New York Community Distributed Generation developers typically offer a 10% utility bill discount for subscribers (*Clean community power* 2022), which is not enough to address chronic energy insecurity (Jessel et al., 2019; Hernández, 2023). To align with CLCPA mandates of 35%–40% benefits for disadvantaged communities, we recommend that community solar programs be expanded and offer greater discounts for LMI customers as well as appropriate levels of incentives to ensure such discounts are feasible and inclusive of households unable to install rooftop solar due to housing tenure status or for financial reasons. Furthermore, the state should incentivize community benefit agreements, which give “communities greater power in terms of their energy choices and the negotiation of broadly distributed benefits” (Vithanage, 2021). These agreements should transfer ownership to land trusts, social justice organizations, participatory budgeting processes to address distributive justice concerns related to community solar.

4.6 Overcoming physical barriers to solar adoption

Participants did not mention barriers to solar that included the physical condition of homes or the state of roof. However, this is a known hindrance to solar adoption. In fact, in considering solar adoption along a continuum of investments towards electrification, it is necessary to consider and invest in weatherization, energy efficiency and structural repairs as earlier steps necessary to support and optimize solar adoption in homes. While participants emphasized economic facets such as the high cost of living in New York City as both a barrier and motivation for solar adoption, the physical state of homes must also be more closely evaluated and upgraded to ready them for electrification and clean energy technologies including rooftop solar.

5 Study strengths and limitations

This study provides evidence from stakeholders most responsible for facilitating access to solar among LMI homeowners. Understanding the perspectives of intended beneficiaries along with implementers and policymakers has revealed barriers, facilitators and critical opportunities for greater alignment with the goal of increasing access to clean energy among

disadvantaged groups. While we have exposed important insights, this study has some noteworthy limitations. First, the study included participants based in and largely focused on NYC, so the findings may not be broadly applicable outside of this context. However, on balance, New York is well ahead of the national sprint toward equitable solar programs, so the information herein can be instructive as other localities design and implement such programs throughout the country. Second, we conducted interviews in the budget season, so we were unable to recruit as many policymakers as we had hoped. Also, recruitment of LMI homeowners which occurred during social distance mandates driven by the COVID-19 pandemic presented many challenges, so we were constrained in the modality of the interviews and recruitment methods. Most households who participated in this study were actively considering solar. This provided us with data related to a specific, non-representative segments of households but did not allow us to answer a key question about why certain households never considered solar. Third, the study excluded renters, who are an important but often neglected target populations in decarbonization efforts. Lastly, the study was focused on LMI households and did not consider racial disparities, even though literature shows the relationship between low solar adoption and high solar potential amongst households of color (Gao and Zhou, 2022). Future studies must be conducted at the intersection of race, socioeconomic and homeownership status to understand underexplored nuance in solar adoption at the critical intersection of those positions.

6 Conclusion

This qualitative study involving perspectives from LMI homeowners, solar implementers and policymakers complements and extends the existing literature on factors that affect access to solar once incentives are active. This New York-based study serves as an early case study of equitable solar adoption whereby state and local policies are supportive of greater participation on the part of disadvantaged groups via financial mechanisms. Yet, barriers persist. For households, the information gap, and administrative and economic burdens are roadblocks even as interest is high for solar in the hopes that it will contain costs and enable environmental stewardship. Implementers highlighted the financial challenges in their execution of necessary but uncompensated work to organize LMI residents and more carefully usher them through the process. CBO implementers noted that there is strong interest and high motivation but also substantial hurdles to overcome to align the incentives with the realities of would-be solar adoptees. Policymakers recognized the important role of external parties in motivating change, while also feeling encumbered by the outsized role of powerful actors in the policymaking process and frustrated about the limitation of a tax-based incentives targeting households with limited tax burdens.

Recognizing the historical mistrust between consumers and the energy industry as a barrier to adopting solar, this paper proposed several policy recommendations. These include developing and financing energy education programs aimed at empowering consumers, implementing bans on predatory practices in the energy domain, enforcing strict accountability measures on

energy providers, and investing in meaningful community engagement initiatives. Additional recommendations include exempting LMI consumers from fees associated with solar expansion funds imposed by energy providers that raise their monthly bill, even as they struggle to find ways to afford utilities and adopt solar. In an effort to identify solar incentive structures that better align with the financial realities of LMI groups, we also recommend reforming the tax structure to allow for a direct pay option, and increasing funding for the development of community-owned solar projects that generate wealth in disadvantaged areas. Future studies may consider expanding on this research by conducting interviews outside of budget season to include more policymaker perspectives and explore the impacts of the IRA on solar adoption perspectives. Future studies could expand on this research by exploring the impact of the IRA on solar adoption and the uptake of other clean energy technologies after programs from this policy have been implemented around the country. Observational data and tracking may be required in various formats to allow for triangulation of viewpoints shared by the interlocutors also noting actual activities to demonstrate where there is alignment, effective and efficient approaches, and outstanding gaps in the implementation process. Ethnographic research, as skillfully done by some social scientists (Lennon, 2017), is necessary to comprehend the dynamics involved to formulate more informed recommendations to improve process and outcomes.

For an equitable energy transition to be realized, there must be an emphasis on purposely addressing the barriers faced by LMI households. New York State has set an exemplary course that has influenced federal-level policymaking. Yet, practicing equity in policy design and program implementation is an ongoing challenge. At present, there is substantial interest in solar among LMI populations and a determination among policymakers and implementers to close access gaps. However, critical barriers remain in making this a reality. We provide recommendations to overcome key challenges in the hopes that solar adoption and a clean energy future will soon be accessible to all.

7 Scope statement

Our manuscript addresses the challenges and opportunities related to the adoption of solar energy among low- and moderate-income (LMI) households, which directly pertains to the goal of producing reliable and affordable energy sources, as emphasized by the journal. Moreover, our study aligns with the United Nations' Sustainable Development Goal (SDG) #7, which is a key focus of the journal, as it seeks to improve access to affordable, reliable, sustainable, and modern energy for all. Our manuscript aligns with the scope of "Frontiers in Energy Research" due to its multidisciplinary exploration of sustainable energy developments.

Specifically, our study investigates barriers and opportunities in the adoption of solar energy among LMI households in New York City where a robust incentive structure at the state and local levels are in place to accelerate rooftop solar uptake among LMI residents. Our qualitative study, based on interviews with policymakers, implementers, and LMI homeowners, uncovers unique insights into the challenges surrounding inclusive solar energy adoption. We highlight significant

differences and mismatches in the perspectives of these stakeholders in the early stages of the incentive roll-out. Our findings reveal that both implementers and LMI homeowners face economic and administrative obstacles, though these factors affect each group differently and act as barriers in distinct ways. By leveraging the viewpoints and experiences of those with policy implementation experience, our manuscript provides evidence-based recommendations for overcoming the barriers hindering equitable and inclusive solar adoption.

Data availability statement

The datasets presented in this article are not readily available. Qualitative data is unavailable to others due to privacy and terms of consent. Requests to access the datasets should be directed to dh2494@cumc.columbia.edu.

Ethics statement

The studies involving humans were approved by the Columbia University Medical Center (IRB-AAA0128). The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants because of the remote format of interviews; consent was audio recorded.

Author contributions

AB: Methodology, Project administration, Writing—original draft, Data curation, Formal Analysis, Writing—review and editing. CD: Data curation, Formal Analysis, Writing—original draft, Writing—review and editing, Validation. EK: Validation, Writing—original draft, Methodology, Project administration, Funding acquisition, Resources. DS: Funding acquisition, Project administration, Resources, Conceptualization, Investigation, Writing—review and editing. DH: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing—original draft, Writing—review and editing.

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Conflict of interest

Authors CD and DS were employed by Kinetic Communities Consulting Corp.

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