frontiers in Sustainable Cities

ORIGINAL RESEARCH
published: 29 April 2021
doi: 10.3389/frsc.2021.632020

Energy Justice Through Solar: Constructing and Engaging Low-Income Households

Yutong Si and Jennie C. Stephens**

School of Public Policy and Urban Affairs, College of Social Sciences and Humanities, Northeastern University, Boston, MA, United States

Minimal research has assessed the policy process of developing solar programs at the state level, and no research yet has investigated how these policies characterize and engage with the target populations they are designed to benefit. Grounded in Schneider and Ingram's social construction framework (SCF) and applying computational methods (i.e., text analysis and machine learning), this research examines how low-income households are socially constructed in policy provisions, how their social construction has been reinforced through public participation, and how to classify low-income households among target populations. Based on the case of Massachusetts, this research analyzes the 2020 Solar Massachusetts Renewable Target (SMART) Emergency Regulation as well as its public comments. We find that low-income households constitute a visible target group of this program and their characterizations as "deserving policy benefits" are positively constructed by policy makers. Furthermore, the conveyed messages and attitudes regarding the assigned benefits to low-income households have been reinforced through public participation. Despite this advantageous positive construction, low-income households have less political power (i.e., measured by topic prevalence in the public comments) than other target groups such as large corporations (e.g., solar developers or solar installers) and less ability to participate or be represented in the policy process, making their voices less likely to be heard by policy makers. With positive social construction but weaker political power, low-income households fall into the category of "dependents" instead of "advantaged," which may engender undesirable policy outcomes minimizing the intended long-term benefits of the policies to low-income households. This research reveals procedural injustices in energy policies and highlights the importance of more inclusive policy-making process, while also offering a novel theoretical lens to understand the rationale and dynamics of developing solar statutes targeting low-income households.

Keywords: energy justice, policy process, social construction, target population, solar, Massachusetts

OPEN ACCESS

Edited by:
Mari Martiskainen, University of Sussex, United Kingdom

Reviewed by:
Trivess Moore, RMIT University, Australia
Raúl Castaño-Rosa, Tampere University, Finland

****Correspondence:***
Yutong Si
si.yut@northeastern.edu
Jennie C. Stephens
j.stephens@northeastern.edu

Specialty section:
This article was submitted to Urban Energy End-Use, a section of the journal Frontiers in Sustainable Cities

Received: *21 November 2020*
Accepted: *11 March 2021*
Published: *29 April 2021*

Citation:
Si Y and Stephens JC (2021) Energy Justice Through Solar: Constructing and Engaging Low-Income Households. Front. Sustain. Cities 3:632020. doi: 10.3389/frsc.2021.632020

INTRODUCTION

Solar photovoltaic (PV) is among the most promising renewable energy technologies with widely acknowledged benefits associated with the environment, health, job creation, community solidarity, and sustainable development worldwide (Millstein et al., 2017; Lee and Shepley, 2020; Zhang et al., 2020). Some countries such as Brazil and China have begun utilizing

solar penetration as a poverty reduction strategy in poor areas (Pereira et al., 2010; Geall et al., 2018). In the United States, however, despite the reduced costs, solar PV continues to be disproportionately installed in higher income communities. Research shows that the growth of solar deployment in the United States over the last decade has not occurred equitably across socioeconomic groups (Sunter et al., 2019; Reames, 2020). Research from GTM Research and PowerScout reveals that in the four states that account for 65% of residential solar installations, most households have incomes between $45,000 and 150,000, which are considered middle-income families, while there are few low-income solar customers involved (Kann and Toth, 2017). More recent evidence indicates that less than half of U.S. community solar projects have any participation from low-income households (Gallucci, 2019). In addition, racial disparities in solar adoption are also prevalent with a recent study showing that Black- and Hispanic- majority census tracts show on average less rooftop PV installed, a disparity that persists even when corrected for household income and home ownership (Sunter et al., 2019). Furthermore, the widening income and wealth gap (Curti et al., 2018; Stephens, 2020) is contributing to the disparities in solar deployment in the United States.

With the recognition of the distributional injustices and disparities that are evident in renewable energy adoption such as solar deployment across different populations, energy justice has become an established research area in the field of energy policy (Fuller and McCauley, 2016; Jenkins et al., 2016, 2020; Reames, 2016; LaBelle, 2017). While there are multiple analytical frameworks and approaches to understand and explore energy justice, both distributive justice and procedural justice are important to consider mirroring the demands of the environmental justice and climate justice movements (Baker et al., 2019). Distributive justice is outcome-oriented and focuses on whether the benefits and burdens of energy are equally distributed, while procedural justice concerns inclusion and equitable access to participation in the decision-making process (Baker et al., 2019). Most of the energy justice literature focuses on distributional disparities and the outcomes of disproportionate adoption, and there is a lack of research analyzing procedural justice of energy policy. This research focuses on the policy process of developing solar programs and contributes to the existing literature on energy justice.

To date, solar adoption in the United States has been driven strongly by the federal Investment Tax Credit (ITC), state renewable portfolio standards (RPS), and state level net energy metering (NEM) laws (Stokes and Breetz, 2018). Incentives provided within these policies generally apply only to those who buy their PV systems outright (i.e., either with a cash purchase or solar loan). These programs, therefore, have ended up targeting middle- and high- income households.

With increasing awareness of how these policies are exacerbating inequities by disproportionately benefiting wealthy communities, policy attention has shifted recently to expand solar opportunities for low-income households. It is widely acknowledged that solar PV has great potential for alleviating energy burdens for low-income households who have been suffering disproportionately from current energy practices and policies while also having to use a higher percentage of their income to pay their energy bills (Cook and Shah, 2018b). The potential benefits of solar to low-income households are large. The U.S. Department of Energy (DOE) has stressed the role of solar PV in helping low-income households reduce their energy burden, and a variety of states have taken measures to integrate solar investments in the Department of Health and Human Services' Low-Income Heating and Energy Assistance Program (LIHEAP) and the Department of Energy's Weatherization Assistance Program (WAP) funded projects (Brown et al., 2020). For example, DOE has authorized Colorado to be the first state to integrate rooftop solar into its WAP program and California has established the Solar on Multifamily Affordable Housing Program and the New Solar Homes Partnership. Many states have incorporated low-income carve-outs into their community solar programs to set aside a portion of money targeting and serving low-income people and integrated rooftop solar into their low-income weatherization assistance policies (Sunter et al., 2019). Solar deployment among low-income households has thus become an important policy objective for many state governments, and policy makers have created a variety of incentive programs focused on energy justice.

While many solar policies and programs targeting low-income households have been formulated and implemented, it is not clear yet whether these programs have achieved their intended objectives of expanding the benefits of solar PV to low-income households. Recent research continues to show minimal participation from low-income households in community solar projects, with the majority of community solar subscribers being businesses, higher education institutions, government agencies, and higher-earning households (Gallucci, 2019).

Existing literature on solar policies has focused on a range of issues including the barriers of promoting solar (Karakaya and Sriwannawit, 2015; Strupeit and Palm, 2016; Mah et al., 2018; Phua, 2020) and more inclusive program design through a more accurate model of utility bill payment performance (Davuluri et al., 2019). Other research has analyzed customers' motivation and satisfaction for low-income solar programs (Lee and Shepley, 2020), state strategies for designing community solar policy such as broadening both on-site and off-site PV (Cook and Shah, 2018a), and disparate rooftop PV installations by race and ethnicity (Sunter et al., 2019). An increasing number of reports have identified multiple barriers to solar adoption including the insufficiency of tax liability and the lack of homeownership in many low-income communities (Paulos, 2017). To summarize, relevant literature provides a valuable lens to understand solar policies and practices, but existing research struggles to explain the policy process of state governments' efforts that promote solar adoption among low-income households in an American context. Although a few recent studies have begun exploring solar programs from a policy perspective (Michaud, 2020), there is no research yet investigating how solar policies have defined, characterized and engaged with target populations, particularly the low-income households for which they are designed to benefit. This study aims at filling these research gaps.

Applying Schneider and Ingram's social construction framework (SCF) to the design of solar policies, this paper provides a new theoretical lens to offer deeper understanding of the rationale and dynamics of developing low-income solar policies at the state level. While the unique paradigm of the social constructionist perspective derives from sociological theories (Berger and Luckmann, 1991), it has been adapted by Schneider and Ingram (1993) to analyze policy design. Analyzing the social construction of target populations involves assessing "the cultural characterizations or popular images of the persons or groups whose behavior and well-being are affected by public policy" (Schneider and Ingram, 1993, p. 334). In other words, social constructions refer to "stereotypes about particular groups of people that have been created by politics, culture, socialization, history, the media, literature, religion, and the like" (Schneider and Ingram, 1993, p. 335). The concept of social constructions is important as it can help us understand the policy process ranging from agenda setting to policy evaluation based on the two primary propositions of the framework—target populations and feed-forward effects (Pierce et al., 2014). While target populations refer to the groups or individuals who achieve policy attention and thus have been chosen for or impacted by public policy, feed-forward effects refer to when a formulated policy "feeds forward to create new policy and politics" through citizen absorption of conveyed social construction as messages (i.e., assigned benefits and burdens) in policies and public participation (Schneider and Ingram, 1993; Pierce et al., 2014). Recent policy literature worldwide has already identified the importance of the characteristics of target populations in the policy process (Si, 2020) and established that the framing and construction of target population matters (Schneider and Ingram, 2017).

In this paper, we adopted a "computational grounded theory" approach (Nelson, 2020) that has been rarely used in the energy policy field and that combines both computational and qualitative methods. The data utilized include the 2020 Solar Massachusetts Renewable Target (SMART) Emergency Regulation along with some guidelines and its public comments, which were obtained from the official website of Massachusetts government. Grounded in the social construction framework and based on computational analysis through coding in Python, this research aims at answering the following questions:

a. How are low-income households defined and characterized in the policy process?
b. How have these characterizations been reinforced or changed through public discourse and public participation?
c. How are low-income households characterized among other target populations?

The first section of this paper introduces the conceptual framework and grounded theory: the policy design theory of social construction framework (SCF) proposed by Schneider and Ingram in 1993. Next, the methods are introduced including the case study design, data collection, data analysis techniques as well as ethical implications. The Results section then provides details on (1) low-income households as a target population; (2) the social construction of low-income households by policy makers; (3) reinforcement of the social construction of low-income households through public participation; and (4) topic modeling and the classification of low-income households. The discussion explores the impacts of these findings, and the final section reflects on some limitations of this study and concludes with future research directions.

CONCEPTUAL FRAMEWORK

Many studies have examined the technical and societal aspects of energy transitions (Burke and Stephens, 2018; Stokes and Breetz, 2018; Allen et al., 2019; Healy et al., 2019). There lacks research exploring the rationale and dynamics of solar deployment from a policy design perspective. The social construction framework (SCF) offers a novel lens to analyze solar policies, contributing to the understanding of why some target groups are more advantaged than others, how policy designs can reinforce or change such advantages, and why some of the seemingly advantaged groups do not actually benefit (Schneider and Ingram, 1993). This framework can help us understand the policy process based on the two primary propositions of the theory—target populations and feed-forward effects (Pierce et al., 2014).

According to Schneider and Ingram's framework, target populations can be classified and categorized based on their social constructions – stereotypes about target groups. Social constructions range from positive to negative. Positive social constructions include images such as "deserving" (deservedness of policy benefits) and "honest" while negative social constructions include images like "undeserving" (requiring policy burdens or penalties to change their behaviors) and "dishonest" (Schneider and Ingram, 1993). The theory contends that there are strong pressures for policy makers to assign benefits to powerful and positively constructed groups while devising burdens to negatively constructed groups (Schneider and Ingram, 1993). Therefore, the stereotypes become embedded in policy as messages that are conveyed and absorbed by the public and affect their perception and participation patterns, thus reinforcing or changing social constructions.

Furthermore, target groups who have stronger political power will tend to gain more benefits and less burdens, and vice versa (Schneider and Ingram, 1993). This is because those people are more active in public participation including voting and policy advocacy, so they are continuously drawing attention from policy makers and reinforcing their positive and engaged role. Therefore, the traditional notions of political power can be revealed through public participation. These feed-forward effects suggest social constructions have long-time effects on our society.

Social constructions and traditional notions of political power suggest a two by two factorial table shown in **Table 1**, which conceptualizes and categorizes target populations as four types. Therefore, target groups include advantaged (i.e., positive social constructions and stronger political power), contenders (i.e., negative social constructions and substantial political power), dependents (i.e., positive social constructions and weaker political power), and deviants (i.e., have neither a positive construction nor stronger political power). Advantaged target

TABLE 1 | Conceptualizing target populations: social constructions and political power.

Political Power	Social Constructions: Positive	Social Constructions: Negative
Stronger	Advantaged - Advantaged target population, such as elderly and business, is likely to receive deservedness of policy intervention and benefits.	Contenders - Contenders, such as unions and the rich, are typically considered as undeserved of government assistance as they are untrustworthy or morally suspicious, and those people are likely to be required policy burdens to punish and change their behaviors.
Weaker	Dependents - Dependents, such as mothers or children, are those who are viewed deserved of sympathy and policy. Low-income households that are targeted by the SMART program fall into this category.	Deviants - Deviants, such as criminals, are unlikely to be aided or impacted by public policy.

Source: Adapted from Schneider and Ingram (1993).

population is likely to receive deservedness of policy intervention and benefits while contenders are typically considered as undeserved of government assistance as they are untrustworthy or morally suspicious, and those people are likely to be required policy burdens to punish and change their behaviors. Dependents are those who are viewed deserved of sympathy and policy intervention to assist, and deviants are unlikely to be aided or punished by public policy.

It is acknowledged, however, that the two dimensions of target populations are hard to measure in reality, especially political power. We see this as one of the limitations of this framework. But it is quite useful when being applied to an empirical context where both social constructions and political power could be understood in a specific scenario. This research offers an example in the field of solar policy as well as insights on how to classify target populations based on their social construction and political power.

While this policy design theory has been applied in various policy fields, ranging from housing policies to veterans benefits (Sabatier, 2007), it has not yet been applied in detail to the context of solar policies. Prior research utilizing this theoretical framework to other policy fields offers evidence of the value of applying a social constructionist typology to understanding target populations in low-income solar programs in the U.S. For example, Drew (2013) utilizes the social construction and policy design theory to explain how and why the U.S. federal government pursued a policy agenda promoting homeownership for low-income households and argues that the social construction of homeownership, low-income households, and the private mortgage industry were instrumental in the policy design process. Similarly, Valcore (2018) applies the framework to examine the hate crime policy to explore whether or not variations in the social and political status of gays and lesbians are related to the inclusion of sexual orientation in the hate crime policy at the state level and contends that target groups seeking hate crime law protection have positive social constructions.

Additionally, Pierce et al. suggest that most research applying this framework focuses on the proposition of target populations while not considering explicitly the feed-forward effects (Pierce et al., 2014). This paper investigates both of the two primary propositions of the theory – target populations and feed-forward effects, thus providing novel insights on and empirical assessment of the application of the theoretical framework.

METHODOLOGY

Grounded in the SCF, this research adopts a "computational grounded theory" approach to better "combine expert human knowledge and skills at interpretation with the processing power and pattern recognition brought by computers" (Nelson, 2020). Schneider and Ingram (1993) suggest that interpretative and qualitative methods based on text are valuable methods for measuring and assessing social construction. Schneider and Ingram (2008) also contend that multiple elements integrated into policy design create social construction, including articulated policy goals, problems to be addressed, eligibility, policy tools, implementation strategy, etc. Pierce et al. (2014) argue that many scholars have utilized qualitative methods based on the SCF framework from 1993 to 2013, but few studies have applied a computational approach to analyzing data. This study combines both computational and qualitative methods to address the research questions and provides insights on the measurement of both social constructions and political power.

The SCF theory argues that not all target populations have a well-defined and unchanging social construction. Depending on policy objectives, for example, policy makers can portray low-income people as lazy individuals or as people whose poverty situations are not their fault. Therefore, the actual social constructions of target groups depend on specific contexts. Using the Massachusetts state solar policies as a case, this study analyzes data from the 2020 Solar Massachusetts Renewable Target (SMART) Emergency Regulation and its public comments. The data were obtained from the official website of the Massachusetts government[1] (downloaded in October 2020) and include the main regulation along with some guidelines and the public comments posted about the regulation. A total of 378 public comments were downloaded and then the 151 repetitive comments (the same comments were posted from multiple individuals from a single environmental organization) were removed. Seven additional public comments that were unreadable (included random numbers, letters, or red lines) were dropped. The total number of public comments prepared for the analysis was 220.

Analysis of the policy-making process of this specific case—a state-level solar policy in Massachusetts—was selected because

[1]https://www.mass.gov/info-details/smart-400-mw-review-emergency-rulemaking.

Massachusetts has been recognized as a national leader on solar, and the state has been actively implementing policies to encourage solar deployment. This case was also chosen because of the publicly accessible data documenting public comments.

The SMART Program is a nation-leading solar energy development program, which was officially launched in 2018 as a transition away from the former Solar Renewable Energy Certificates (SREC) program. The SMART incentive program is designed to benefit all qualified solar generation units and includes specific funding for low-income neighborhoods. The policy aims to encourage solar development by paying system owners a set rate per kilowatt-hour of power generated. The base rate is determined by the size of the installation and the utility territory in which it is located (i.e., in this program, the electricity distribution utilities and the sponsors of the program include Eversource, National Grid, and Unitil) (Shemkus, 2020). The compensation rate decreases as more projects apply for incentives. Projects with features the state hopes to encourage (e.g., integrated energy storage or location on a rooftop) have a few extra cents added to their rate, known as an "adder" (Shemkus, 2020). On April 14, 2020, the Massachusetts Department of Energy Resources (DOER) filed a revised SMART program with the Secretary of the Commonwealth as an emergency regulation. The main revisions of the 2020 ruling include: (1) an expansion of the SMART program size from 1,600 to 3,200 MW; (2) an expansion of the definition of a low-income customer; and (3) an additional prohibition of solar deployment on land where at least 50% of the parcel's area is designed as Priority Habitat or Critical Natural Landscape (i.e., the development of a web mapping tool to help identify these areas was also included) (SMART Emergency Regulation, 2020). These changes to the rule, especially the details about land-use, attracted considerable attention among stakeholders. Written comments were collected from April 14 to June 1, 2020. The public could submit written comments via email or mail to the DOER.

The texts of the new SMART ruling and the public comments were downloaded from the government website and transferred to plain texts through Adobe Acrobat Pro DC software and uploaded in the data folder of Jupyter Notebook. Then computational methods through Python programming code implementation were applied. Names of participants who posted public comments have been left out of the paper.

Multiple basic functions of computational text analysis were used in Python. The "word count" function, which sorts frequency of certain words of interest, is important in this research as it can help capture and measure attention being paid to different framings and themes by both the policy makers who drafted the policy and those who may read and interpret the policy. Specifically, to identify the visible target population of the incentive program, we first counted the 50 most frequent words to get an overall sense of the content of the regulation. Then, we counted how many times "income" appeared in the policy provision and in which contexts does the word appear in the policy provision based on the "word count" and "concordance" (i.e., index of instances of a given word) functions in Python, presenting each occurrence of the given word "income" together with some context. Second, to identify how low-income households are characterized by policy makers in the policy provision as well as their social constructions within the SMART provision, the "cooccurrence" function was executed in Python, which takes a filename containing a text file and a word as a string as input and outputs the most frequent words that occur in the same sentence as the target word. The same analysis was conducted with the obtained 220 public comments. To complement the computational analysis, we also examined the original data and combined qualitative methods to analyze the data in an inductive way.

Furthermore, to identify other target groups and clearly classify low-income households, our analysis used the topic modeling approach, which is an unsupervised machine learning method to uncover abstract topics within a text, to naturally obtain embedded themes and identify involved actors/stakeholders in the public comments. The data was analyzed at the document level (i.e., each public comment) through topic modeling. This investigation implemented the topic modeling algorithm of Latent Dirichlet Allocation (LDA), which does not take the document order into account. It uses the co-occurrence of words within documents, compared to their distribution across documents, to uncover abstract themes. By fitting the data into the LDA models, it is possible to create a list of weighted words, which indicate the subject of each topic, and a weight distribution across topics for each document. Analysis by topic distribution identifies representative texts for each topic and discusses the meaning of topics. We also created an interactive visualization through pyLDAvis to view the topics-keywords distribution, analyzing the meaning of each topic, the prevalence of each topic, and relation/relevance between each topic. The number of topics and the specific interpretation of the emerged themes (e.g., examining representative texts for each topic) were obtained with a qualitative approach.

RESULTS

Low-Income Households as a Target Population

The target population of a policy refers to "a concept derived from the policy design literature that directs attention to the fact that policy is purposeful and attempts to achieve goals by changing people's behavior" (Schneider and Ingram, 1993, p. 335). By specifying eligibility in the regulation along with its guidelines, policy establishes boundaries of target groups. Behavior change of target populations would be expected by articulating eligibility in the policy provision.

The stated policy objective at the beginning of the MA 2020 SMART Emergency Rule is to "establish a statewide solar incentive program to encourage the continued use and development of generating units that use solar photovoltaic technology by residential, commercial, governmental and industrial electricity customers throughout the Commonwealth" (SMART Emergency Regulation, 2020). Based on the policy objective in the original text and the most frequent words, we see that the statute aims at regulating solar generation within

Massachusetts. It is an incentive program containing words like "tariff," "compensation," "adder," "block," etc. There are some words which can help us further explore the eligibility of target populations in the policy provision, such as "income," "eligible," and "qualification."

Following that, by looking at a variety of "concordances" of "income," we find that the word of "income" appeared 42 times in total in the 2020 SMART Emergency Regulation, and 39 of them are used together with the word "low." This indicates that low-income households are one of the most critical and visible target populations and have been paid a lot of attention in terms of policy intervention in the SMART program.

We combine computational results and the policy provision in an inductive way to better illustrate the visible target population of the policy. By deeply looking into the regulation and its guidelines, a low-income customer is defined as "an End-use Customer that qualifies as a low-income customer under the applicable rate class with its local Distribution Company." Three types of low-income solar generation facilities are eligible for the benefit including: (1) Low Income Community Shared Solar Tariff Generation Unit, with at least 50% of its energy output allocated to Low Income Customers in the form of electricity or net metering credits; (2) Low Income Solar Tariff Generation Unit, with an AC rated capacity of $\leq$25 kW that serves Low Income Customers; and (3) Low Income Property Solar Tariff Generation Unit: with a rated capacity $>$ 25 kW that provides all of its generation output in the form of electricity or net metering credits to low or moderate income housing (SMART Emergency Regulation, 2020).

By specifying eligibility criteria and differentiating incentive levels, the program delivers a clear message to the public that low-income households are targeted and prioritized under the SMART program and low-income customers should be able to receive the same benefits as other residents.

The Social Construction of Low-Income Households by Policy Makers

Schneider and Ingram (1993, p. 335) noted that "the actual social constructions of target groups, as well as how widely shared the constructions are, are matters for empirical analysis," suggesting that social constructions are measurable phenomena. They also noted that social constructions are usually conflicting. For example, with the words and framing included in specific policies, policy makers can portray low-income people in a certain way. Depending on what words are used, low-income households can be considered for special policy provisions because they do not work hard or because their poverty situations are a result of bad luck or structural issues that are not their fault. According to the SCF, positive constructions include policy images like "deserving," "intelligent," "honest," etc. while negative constructions include the opposite message such as "undeserving" (Schneider and Ingram, 1993).

To identify the social construction of low-income households embedded within the SMART program, we explored the "cooccurrences" (i.e., index of instances of a given word) of "low income" in the policy provision, presenting each occurrence of "low income" together with some context. The results show that the words of "low income" are always together with another word that further describes the population including words like "tariff," "community," "shared," "compensation," "less," and "equal" in the same sentence.

The results suggest that low-income people could benefit from the policy by receiving compensation for their expenses and a variety of compensation adders[2] for solar adoption. The policy delivers a message that low-income people are worthy of receiving policy benefits instead of policy burdens; this indicates that low-income households are positively constructed in the policy.

To gain better understanding regarding "less" and "equal," we came back to the policy provision as these words can be confusing. When looking at the original document, we find that the policy makers use these two words to refer to income eligibility or the capability of solar generation units (i.e., encouraging small scale solar generation units and distributive solar). For example, a low-income eligible area refers to "a neighborhood that has household income $\leq$ 65% of the statewide median income for Massachusetts" and a low-income solar tariff generation unit refers to "a solar tariff generation unit with an AC rated capacity of $\leq$25 kW that serves low-income customers" (SMART Emergency Regulation, 2020). This indicates that eligibility criteria of the target population are emphasized when constructing low-income customers in the policy provision.

Reinforcement of the Social Construction of Low-Income Households Through Public Participation

In addition to the first proposition regarding target populations, the SCF also suggests that social constructions, as the delivered messages about assigned benefits or burdens embedded in the policy, can be absorbed by the public and impact public participation. That being said, policy plays an important role in shaping citizen orientations and reinforces or changes certain views of citizenship that are in turn linked to distinct participation among groups. This process can have long-lasting effects on our society as it can affect future politics and policies. One of the important mechanisms of public participation in the policy process is the opportunity for public commenting on proposed policies (Innes and Booher, 2004). Public comments provide a mechanism for anyone to deliver public concerns to policy makers. Therefore, analyzing public comments of new policies is one way to identify the "feed-forward effects" of policies and understand the role of public participation in the policy process (Schneider and Ingram, 1993).

Using the "word count" and "cooccurrence" functions in Python to analyze the public comments, we are able to assess how the public perceives low-income households. Do

[2]Note: "The SMART program also offers 'adders' that will earn you more money if your system has certain characteristics. For instance, installing a battery storage system with your panels can qualify you for the energy storage adder, which will give you additional savings per kWh. Installing a system on a brownfield will also qualify you for an adder." See https://www.solarreviews.com/blog/massachusetts-smart-program-replaces-srecs.

the public comments reinforce a caring attitude toward low-income communities? Do the public comments reflect agreement that low-income people deserve policy benefits? The public comments provide insights on whether the characterization of low-income households constructed in the policy have been reinforced or changed through public participation.

Among the 220 public comments, about 27 participants mentioned "low income" in their submitted comments while 193 participants did not. The fact that nearly 13% of individuals mentioned "low income" people indicates that those communities did receive public attention to some extent[3].

The goal of this analysis is not to examine how many of the public comments mentioned low-income households. Rather, we aim to explore whether the social construction of low-income households has been reinforced through the public comment period. Therefore, we performed the "cooccurrence" function, which demonstrates that the public comments that contain "low income" are largely consistent with the characterizations presented in the policy provision – the deservedness of policy benefits for low-income households. Many comments included explicitly positive framing, such as the word "applaud" when talking about "low income," which indicates support for the policy and appreciation for the explicit consideration of low-income households and individuals. The social construction of low-income households through these public comments is revealed in the words like "vulnerable," "vulnerability," "risk," "justice," "benefit," "help," "inequity," "inclusion," etc. in the obtained public comments. These words show that the social construction of low-income households delivered by policy makers have been reinforced and strengthened through public participation, which means that the stereotypes are likely to have long-lasting effects that will impact future policies and politics.

Topic Modeling and the Classification of Low-Income Households

Despite the positive social construction of low-income households in the policy and the reinforcement of this policy stance through public participation, it remains unclear why low-income households are not benefiting from solar (current research continues to show disproportionate and unequal adoption of solar across demographics). Remember that we have not explored political power so far. According to the SCF, people with stronger political power are generally more active in public participation including voting and policy advocacy, thus continuously drawing attention from policy makers and reinforcing their positive and engaged role. In other words, the advantaged groups are likely to mobilize themselves to pursue their self-interests through public participation while dependents do not see themselves as effective in the public discourse and are likely to show passive styles of public participation (Schneider and Ingram, 1993).

Recognizing this, it would be helpful to explore and quantify political power by different target groups in this policy arena in order to classify low-income households in the social constructionist typology. We measured political power though the obtained public comments according to topic prevalence through topic modeling (i.e., unsupervised machine learning), which contributes to the application of the SCF and offers an initial attempt as well as an example regarding the measurement of political power through a machine learning approach.

Five topics naturally emerged in the public comments: (1) Topic 1 (4.6% of tokens) focuses on low-income households and is represented by solar organizations and coalitions, non-profits, and government agencies; (2) Topic 2 (55.3% of tokens) emphasizes the benefit-cost ratio and the land use issue, and this topic is represented by corporations (e.g., solar installers, solar developers, technology companies, digital energy service platforms, renewable energy resource companies, etc.); (3) Topic 3 (13.4% of tokens) is about the land use issue as well as the nature, climate issues, conservation, habitats, etc., and this topic is represented by environmental organizations; (4) Topic 4 (8.8% of tokens) represented by individuals from different towns talks about the land use issue (oppose the restriction of disqualification of habitats or natural lands in the regulation), job creation, economic development, and residents or landowners in towns; and (5) Topic 5 (17.9% of tokens) focuses on habitat conservation and forestation, and this topic is represented by environmental advocates. As we can see, several topics such as themes relevant to "land use" and "income" have received wide attention from the public, which are also main changes of the 2020 emergency ruling mentioned previously.

Analyzing the prevalence of different topics from different stakeholders reveals who is participating and who is dominating the conversation, which also offers a novel lens to measure political power in this context. Comments by large corporations such as solar installers or developers account for more than half (55.3%) of the corpus, representing the interests of the solar industry and mainly focusing on the revised land use provisions and local communities' revenues. Their stance is similar to the fourth topic represented by residents in towns, which accounts for about 8.8% of the corpus. Those residents who live in different towns are concerned about jobs, revenues, etc. By contrast, the third topic and the fifth topic represented by environmental organizations or environmental advocates are supporting the new land use ruling and advocating for the prohibition of solar installation on "Priority Habitat," "Core Habitat," or "Critical Natural Landscape." These two topics account for about 31.3% of the corpus in total. As we can see, there is a tension between the identified topics-the controversy between environmental protection and economic development. In addition, the least prevalent topic (about 4.6% of the corpus), which emerged from comments represented by solar coalitions, non-profits, and government agencies, emphasizes more about Massachusetts low-income residents, advocating for crafting low-income customers in a way that it identifies electricity customers who are currently low-income.

Based on the results, we argue that, in the public participation process, although low-income households did receive public attention to some extent and the social construction of low-income households were reinforced, the topic emphasizing and

[3]Note that the 151 repetitive comments that were deleted from the corpus all contain "low income." To strengthen the argument and perform better topic modeling afterwards, we did not include them in the analysis.

focusing on low-income households is the least prevalent in the corpus. Attention to low-income households is relatively low compared to other issues such as land use, and low-income households themselves or individuals who clearly represent them are not likely to be commenting on the solar policies – most of the comments addressing low-income households are from coalitions, organizations or government agencies. Questions also remain whether these participants could actually represent low-income households and deliver their actual concerns to policy makers.

DISCUSSION

This research contributes to the understanding of why some target groups are advantaged in the policy-making process, how policy designs can reinforce or change these advantages, and how to classify low-income households among target populations. This analysis shows that low-income households have been identified and prioritized as a visible target population in the SMART program, and the positive social construction (i.e., deservedness of policy benefits) of low-income households makes them more advantaged in the program. But with weaker political power compared with other target groups (i.e., large corporations such as solar developers or solar installers in this case), they are less likely to enjoy policy benefits and fall into the category of "dependents" instead of "advantaged."

The benefits of solar along with its decreasing costs provides a critical justification for policy makers to popularize solar. The political discourse on the climate crisis in Massachusetts also facilitated a transition to renewable energy. In other words, the long-standing political norms are beneficial for the growth of the solar industry within the state, which may provide the solar industry with some advantaged social constructions (i.e., we didn't specifically explore the social construction of large solar corporations as we did for low-income households). As a consequence, the Massachusetts' solar industry has been recognized as a national leader in the U.S.

Targeting low-income households is also justified by the emerging concerns around energy justice (Healy et al., 2019; Jenkins et al., 2020; Stephens, 2020) and environmental justice (Roddis et al., 2018; Lukanov and Krieger, 2019). These growing concerns play a key role in justifying the rationale of solar policies targeting low-income households and assigning policy benefits to that target group given the existing adoption disparities (distributional injustices). Therefore, low-income households have been constructed and "portrayed" as deserving policy benefits. Explicit investment in low-income households could also be considered a form of reparatory justice.

Furthermore, the conveyed message about assigned benefits to the public has reinforced the social construction of low-income households and strengthened their deservedness of policy benefits, based on the fact that the characterization of low-income households constructed by those who mentioned low-income people in their comments are largely consistent with the policy stance.

Despite the positive social construction of low-income households in the SMART program, however, due to long-lasting structural problems such as homeownership policies, historic contract granting utilities monopoly power over the grid (Burke and Stephens, 2018), etc., low-income households have weaker political power and therefore are less empowered to participate or be represented in the policy making process. Therefore, although low-income households are being targeted, the concerns, perspectives, and priorities from this target group were not likely to be delivered to policy makers through the public comment process (i.e., given the least prevalence of the topic focusing on low-income people in the corpus). By contrast, large corporations such as solar developers or solar installers dominate the discourse (i.e., the topic represented by this target group accounts for more than half of the corpus). These stakeholders are more likely to continue receiving policy benefits, because their voices and concerns are more likely to be considered by policy makers, reinforcing their advantaged and engaged role in the policy process. With positive social construction but weaker political power, low-income households fall into the category of "dependents" in the social constructionist typology of target populations (see **Table 1**).

Therefore, the program may not be actually benefiting low-income households who are having and continue to have disproportionately higher energy burdens than others. To change the status quo and make solar PV actually benefit low-income people, policy makers should design more inclusive policy process and focus more on procedural justice when formulating solar policies in order to allow low-income residents to engage directly or be represented. Leadership should be developed from underrepresented or marginalized communities to empower those individuals. As the results suggest, those who care about low-income households are more likely to be coalitions, non-profits, and government agencies. Non-profits may play an important role in terms of motivating as well as representing low-income households. Without meaningful and effective community engagement of low-income households in the policy-making process, it will continue to be difficult to have inclusive community support and engagement which is necessary to achieve the intended outcomes of these policies.

CONCLUSIONS

Applying the policy design perspective to the energy policy research provides a novel theoretical contribution and offers a deeper understanding of the rationale and dynamics of the policy process of developing low-income solar policies at the state level. By utilizing the SCF in an empirical context, this research contributes to the understanding of why some target groups are more advantaged than others, how such advantages can be reinforced through public participation, and how to categorize low-income households among target populations.

The patterns revealed here in the case of Massachusetts are likely playing out in other states and other jurisdictions that are trying to expand solar policies to be inclusive of low-income households. The data-driven and inductive approach

shows that the social construction (i.e., stereotypes) of low-income households, who have been identified as a visible target population that deserves policy benefits, results in low-income households being advantaged by the program. The conveyed message about assigned benefits to the public has reinforced and strengthened the social construction of low-income households – the deservedness of policy benefits. Despite the fact that the policy stance is beneficial to that target group, they have weaker political power and are less empowered to participate in the policy process, making their voices less likely to be heard by policy makers and be truly enjoying the benefits of solar. By contrast, other target groups such as large corporations who have stronger political power are more likely to participate in the policy-making process and receive policy benefits in the long run, reinforcing their advantaged and engaged role. More broadly, this research highlights the ongoing challenge of more meaningful representation and direct engagement of low-income households when formulating solar policies and the importance of concerning procedural justice in order to address the issues of energy injustices.

Our research is an initial and novel contribution to the literature. Local governance and policy formulation, however, may contain a specific context. Further research in other scenarios needs to be done to explore how solar policies have engaged with low-income households. Also, since Massachusetts is a national leader on solar, a question remains regarding the applicability of the paper's conclusions to other states. In addition, further research using first-hand data is needed to better understand the policy process of state-level solar policies. Valuable future contributions could utilize other measurements to quantify social constructions and political power. Further studies could also assess the tensions embedded in solar programs, the degree to which public comments are well-considered by policy makers, how public discourse as portrayed in social media corresponds or diverges from public comments, and how a broader diversity of target populations is categorized and framed in solar energy policy.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available at: https://www.mass.gov/info-details/smart-400-mw-review-emergency-rulemaking.

AUTHOR CONTRIBUTIONS

YS developed the theoretical framework, collected and analyzed the data, and wrote the draft of the manuscript. JCS supervised the project, provided critical feedback, edited the draft, and helped shape the research. All authors contributed to the manuscript.

REFERENCES

Allen, E., Lyons, H., and Stephens, J. C. (2019). Women's leadership in renewable transformation, energy justice and energy democracy: redistributing power. *Energy Res. Soc. Sci.* 57:101233. doi: 10.1016/j.erss.2019.101233

Baker, S. H., DeVar, S., and Prakash, S. (2019). *The Energy Justice Workbook. Initiative for Energy Justice*. Available online at: https://iejusa.org/workbook/ (accessed February 14, 2021).

Berger, P. L., and Luckmann, T. (1991). *The Social Construction of Reality: A Treatise in the Sociology of Knowledge (Issue 10)*. New York, NY: Penguin Uk.

Brown, M., Soni, A., Lapsa, M. V., Southworth, K., and Cox, M. (2020). Low-income energy affordability in an era of U.S. energy abundance. *Prog. Energy* 2:4. doi: 10.1088/2516-1083/abb954

Burke, M. J., and Stephens, J. C. (2018). Political power and renewable energy futures: a critical review. *Energy Res. Soc. Sci.* 35, 78–93. doi: 10.1016/j.erss.2017.10.018

Cook, J. J., and Shah, M. (2018a). *Focusing the Sun: State Considerations for Designing Community Solar Policy (NREL/TP-6A20-70663)*. Golden, CO: National Renewable Energy Lab. (NREL).

Cook, J. J., and Shah, M. (2018b). *Reducing Energy Burden with Solar: Colorado's Strategy and Roadmap for States (NREL/TP−6A20-70965, 1431421; p. NREL/TP−6A20-70965, 1431421)*. Golden, CO: National Renewable Energy Lab. (NREL).

Curti, J., Andersen, F., and Wright, K. (2018). *A Guidebook on Equitable Clean Energy Program Design for Local Governments and Partners*. Vol. 84. Port Washington, Wisconsin, Urban Sustainability Directors Network (USDN).

Davuluri, S., Franceschini, R. G., Knittel, C., Onda, C., and Roache, K. (2019). *Machine Learning for Solar Accessibility: Implications for Low-Income Solar Expansion and Profitability (No. w26178; p. w26178)*. Cambridge, MA: National Bureau of Economic Research.

Drew, R. B. (2013). Constructing homeownership policy: social constructions and the design of the low-income homeownership policy objective. *Hous. Stud.* 28, 616–631. doi: 10.1080/02673037.2013.760030

Fuller, S., and McCauley, D. (2016). Framing energy justice: perspectives from activism and advocacy. *Energy Res. Soc. Sci.* 11, 1–8. doi: 10.1016/j.erss.2015.08.004

Gallucci, M. (2019). *Energy Equity: Bringing Solar Power to Low-Income Communities*. Yale Environment360. Available online at: https://e360.yale.edu/features/energy-equity-bringing-solar-power-to-low-income-communities (accessed February 14, 2021).

Geall, S., Shen, W., and Gongbuzeren. (2018). Solar energy for poverty alleviation in China: state ambitions, bureaucratic interests, and local realities. *Energy Res. Soc. Sci.* 41, 238–248. doi: 10.1016/j.erss.2018.04.035

Healy, N., Stephens, J. C., and Malin, S. A. (2019). Embodied energy injustices: unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains. *Energy Res. Soc. Sci.* 48, 219–234. doi: 10.1016/j.erss.2018.09.016

Innes, J. E., and Booher, D. E. (2004). Reframing public participation: strategies for the 21st century. *Plan. Theory Pract.* 5, 419–436. doi: 10.1080/1464935042000293170

Jenkins, K. E. H., McCauley, D., Heffron, R., Stephan, H., and Rehner, R. (2016). Energy justice: a conceptual review. *Energy Res. Soc. Sci.* 11, 174–182. doi: 10.1016/j.erss.2015.10.004

Jenkins, K. E. H., Stephens, J. C., Reames, T. G., and Hernández, D. (2020). Towards impactful energy justice research: transforming the power of academic engagement. *Energy Res. Soc. Sci.* 67:101510. doi: 10.1016/j.erss.2020.101510

Kann, S., and Toth, A. (2017). *How Wealthy Are Residential Solar Customers?*. GTM Squared. Available online at: https://www.greentechmedia.com/squared/the-interchange-podcast/how-wealthy-are-residential-solar-customers (accessed February 14, 2021).

Karakaya, E., and Sriwannawit, P. (2015). Barriers to the adoption of photovoltaic systems: the state of the art. *Renew. Sustain. Energy Rev.* 49, 60–66. doi: 10.1016/j.rser.2015.04.058

LaBelle, M. C. (2017). In pursuit of energy justice. *Energy Policy* 107, 615–620. doi: 10.1016/j.enpol.2017.03.054

Lee, J., and Shepley, M. M. (2020). Benefits of solar photovoltaic systems for low-income families in social housing of Korea: renewable energy applications as solutions to energy poverty. *J. Build. Eng.* 28:101016. doi: 10.1016/j.jobe.2019.101016

Lukanov, B. R., and Krieger, E. M. (2019). Distributed solar and environmental justice: exploring the demographic and socio-economic trends of residential PV adoption in California. *Energy Policy* 134:110935. doi: 10.1016/j.enpol.2019.110935

Mah, D. N., Wang, G., Lo, K., Leung, M. K. H., Hills, P., and Lo, A. Y. (2018). Barriers and policy enablers for solar photovoltaics (PV) in cities: perspectives of potential adopters in Hong Kong. *Renew. Sustain. Energy Rev*. 92, 921–936. doi: 10.1016/j.rser.2018.04.041

Michaud, G. (2020). Perspectives on community solar policy adoption across the United States. *Renew. Energy Focus* 33, 1–15. doi: 10.1016/j.ref.2020.01.001

Millstein, D., Wiser, R., Bolinger, M., and Barbose, G. (2017). The climate and air-quality benefits of wind and solar power in the United States. *Nat. Energy* 2, 1–10. doi: 10.1038/nenergy.2017.134

Nelson, L. K. (2020). Computational grounded theory: a methodological framework. *Sociol. Methods Res*. 49, 3–42. doi: 10.1177/0049124117729703

Paulos, B. (2017). *Bringing the Benefits of Solar Energy to Low-Income Consumers*. p. 72. Available online at: https://www.cesa.org/wp-content/uploads/Bringing-the-Benefits-of-Solar-to-Low-Income-Consumers.pdf (accessed February 14, 2021).

Pereira, M. G., Freitas, M. A. V., and da Silva, N. F. (2010). Rural electrification and energy poverty: Empirical evidences from Brazil. *Renew. Sustain. Energy Rev*. 14, 1229–1240. doi: 10.1016/j.rser.2009.12.013

Phua, P. (2020). *The Case for Low-Income Solar: Exploring the Obstacles to Solar for LMI Households and Potential Opportunities to Advance Access [Report]*. Available online at: http://conservancy.umn.edu/handle/11299/216528 (accessed February 14, 2021).

Pierce, J. J., Siddiki, S., Jones, M. D., Schumacher, K., Pattison, A., and Peterson, H. (2014). Social construction and policy design: a review of past applications. *Policy Stud. J.* 42, 1–29. doi: 10.1111/psj.12040

Reames, T. G. (2016). Targeting energy justice: Exploring spatial, racial/ethnic and socioeconomic disparities in urban residential heating energy efficiency. *Energy Policy* 97, 549–558. doi: 10.1016/j.enpol.2016.07.048

Reames, T. G. (2020). Distributional disparities in residential rooftop solar potential and penetration in four cities in the United States. *Energy Res. Soc. Sci*. 69:101612. doi: 10.1016/j.erss.2020.101612

Roddis, P., Carver, S., Dallimer, M., Norman, P., and Ziv, G. (2018). The role of community acceptance in planning outcomes for onshore wind and solar farms: an energy justice analysis. *Appl. Energy* 226, 353–364. doi: 10.1016/j.apenergy.2018.05.087

Sabatier, P. A. (2007). *Theories of the Policy Process*. 2nd Edn. Boulder, MO: Westview Press.

Schneider, A., and Ingram, H. (1993). Social construction of target populations: implications for politics and policy. *Am. Political Sci. Rev*. 87, 334–347. doi: 10.2307/2939044

Schneider, A., and Ingram, H. (2008). "Social constructions in the study of public policy," in *Handbook of Constructionist Research*, ed J. Holstein (New York, NY: Guilford Publications), 189–211.

Schneider, A., and Ingram, H. (2017). "Framing the target in policy formulation: the importance of social constructions," in *Handbook of Policy Formulation*. Available online at: https://www.elgaronline.com/view/edcoll/9781784719319/9781784719319.00028.xml (accessed February 14, 2021).

Shemkus, S. (2020). "Massachusetts proposal doesn't address low-income solar barriers, advocates say," in *Energy News Network*. Available online at: https://energynews.us/2020/02/07/northeast/massachusetts-proposal-wont-address-low-income-solar-barriers-advocates-say/ (accessed February 14, 2021).

Si, Y. (2020). Implementing targeted poverty alleviation: a policy implementation typology. *J. Chin. Gov.* 5, 439–454. doi: 10.1080/23812346.2020.1802212

SMART Emergency Regulation. *Pub. L. No. 225 CMR 20.00* (2020). Available online at: https://www.mass.gov/info-details/smart-400-mw-review-emergency-rulemaking (accessed October 28, 2020).

Stephens, J. C. (2020). *Diversifying Power: Why We Need Antiracist, Feminist Leadership on Climate and Energy*. Washington, DC: Island Press.

Stokes, L. C., and Breetz, H. L. (2018). Politics in the U.S. energy transition: case studies of solar, wind, biofuels and electric vehicles policy. *Energy Policy* 113, 76–86. doi: 10.1016/j.enpol.2017.10.057

Strupeit, L., and Palm, A. (2016). Overcoming barriers to renewable energy diffusion: Business models for customer-sited solar photovoltaics in Japan, Germany and the United States. *J. Clean. Prod*. 123, 124–136. doi: 10.1016/j.jclepro.2015.06.120

Sunter, D. A., Castellanos, S., and Kammen, D. M. (2019). Disparities in rooftop photovoltaics deployment in the United States by race and ethnicity. *Nat. Sustain*. 2, 71–76. doi: 10.1038/s41893-018-0204-z

Valcore, J. L. (2018). Sexual orientation in state hate crime laws: exploring social construction and criminal law. *J. Homosex*. 65, 1607–1630. doi: 10.1080/00918369.2017.1380992

Zhang, H., Wu, K., Qiu, Y., Chan, G., Wang, S., Zhou, D., and Ren, X. (2020). Solar photovoltaic interventions have reduced rural poverty in China. *Nat. Commun*. 11:1969. doi: 10.1038/s41467-020-15826-4

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.