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Accessibility in sustainability transitions: U.S. electric utilities' deployment of solar

Ekundayo Shittu [a,*], Carmen Weigelt [b]

[a] Department of Engineering Management and Systems Engineering, The George Washington University, Washington, DC, 20052, USA
[b] A.B. Freeman School of Business, Tulane University, New Orleans, LA, 70118, USA

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ABSTRACT

Several policies promote the adoption of renewable electricity among incumbent utilities. Yet, the scale of consumer adoption appears limited by accessibility. The underlying factors inhibiting accessibility are exacerbated with low- and middle-income (LMI) consumers who not only have substantial income disparities but also make up a significant proportion of a utility's customer base. While prior research demonstrates that policies can help in scaling participation hurdles in solar, the extent to which utility efforts help to unlock the market potential for LMI participation is not evident. We contribute to distributional effects of environmental policy by evaluating utilities' efforts to provide consumer access to clean energy. Reviewing solar initiatives of utilities, as reflected on their website enhanced with secondary archival data, we find that the role of accessibility particularly for LMI households, either through community solar projects (CSP) or rooftop solar installations, is shaped by policy and complementary factors. Such factors include ownership models either through subscriptions or rooftop panel ownership, income disparity, the regulatory regime, and a combination of these factors. Our findings further suggest that utilities are more likely to support LMI accessibility to their CSPs in the presence of policy intervention such as solar incentives and retail choice markets when their customer base is significantly LMI households. In fact, LMI access by subscription is stronger in retail choice markets, whereas access to rooftop solar panels is an increasing function of income.

1. Introduction

Efforts to address climate change require sustainability transitions to technological systems that decarbonize the economy. Such decarbonization initiatives in electricity generation include investments in renewables such as wind and solar. Although policies incentivize private actors to embrace clean technologies, the extent to which consumers have access to clean technologies is still to be seen. The management literature on technology diffusion posits that sustainability transitions may be limited due to consumer accessibility to clean technologies for reasons ranging from consumer satisfaction (Simpson and Clifton, 2015), the income effect (Burlinson et al., 2018), features (Foray et al., 2012), design reliability (Pakravan and MacCarty, 2020; Deluque et al., 2018), environmental beliefs and benefits (Shubbak, 2019), to the degree of knowledge spillover (Conti et al., 2018), amongst other factors.

Paradoxically, the diffusion of innovations literature highlights that consumer attitudes to system attributes inform consumer hesitance to adopt a technology (Faiers and Neame, 2006). The argument on consumer adoption progression is underscored by how access is a function of the relations between firms and their customer base, especially if latter faces wide disparities in consumer income. Thus, this paper explores the interplay between customer income and policy in affecting consumer accessibility to solar electricity in the United States. Our findings demonstrate that accessibility, particularly for low and middle income (LMI) households, either through community solar projects (CSP) or rooftop solar installations, is shaped by the presence of complementary factors. Furthermore, this paper examines consumer accessibility to solar via CSP subscriptions or panel ownership. Under the three levers of accessibility, *i.e.*, CSP access, rooftop solar accessibility support, and ownership models, this paper sheds light on the value of policy, the role of customer base income, and the combination of policy and customer base income effects on the three levers.

Some U.S. states such as Colorado, Minnesota, New Jersey, and California have mandated utilities to develop shared solar projects (Chang et al., 2017). Their state-level policies are mainly geared at eligibility and credits calculations and have impacts on market

* Corresponding author.
E-mail addresses: eshittu@gwu.edu (E. Shittu), cweigelt@tulane.edu (C. Weigelt).

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participants and developers. For example, Colorado has enacted the Community Solar Garden Act (CSGA) that supports shared solar for low-income residents (McLaren, 2014). For example, Grand Valley Power utility's CSP in Colorado is subscription-based and serves eight LMI households. Subscribers to the CSP receive a monthly net-metering credit of about $50 per month and pay no up-front costs but a fee of about $9 a month. Fort Collins Utilities' CSP serves about 20 LMI households and is supported by Colorado's Low-Income Energy Assistance Program (LIHEAP) (Heeter et al., 2017).

The role of utilities in enhancing consumer accessibility to solar is further magnified when the customer base is inclusive of LMI households. While factors such as the reduction in installation costs, incentives, and consumer willingness all combine to promote interest in CSP or rooftop solar, the participation of the LMI group is significantly low, only representing 15% of solar adopters (Barbose et al., 2018). In the U.S., forty-four percent of households are considered low-income with 60–80% below the median income. Their energy expenditure is an average of 8.6% of their income (DOE OEERE, 2020).

Community solar "refers to local solar facilities shared by multiple community subscribers who receive credit on their electricity bills for their share of the power produced." (SEIA, 2020). We study utility-sponsored community solar that is utility-owned or operated. Community solar installation capacity tends to be five MW or less and is often located within the same county as the customer. Community solar benefits consumers without private rooftops or the financial resources to purchase or finance solar panel installations. A 2015 Greentech Media study estimated that about 77% of U.S. residential households were potential CSP participants. While prior research has demonstrated that policies can lower barriers to LMI household participation in community solar (O'Shaughnessy et al., 2021; Gai et al., 2021), the extent to which utility actions (or inactions) help to unlock the market potential for LMI participation is not evident.

The nebulous challenges that incumbents face in technology transitions also pertain to coupling a new business model with consumer access. Several studies show that the adoption of a focal good is positively correlated with the presence of complementary goods or services (Corts, 2010; Goldenberg et al., 2010). Therefore, in the case of solar electricity, it is crucial to understand how customer base income and policy combine with complementary services offered by utilities to advance consumer accessibility – a prerequisite for the success of sustainability transitions. The gap in the literature is the dearth of knowledge on the extent to which incumbents promote greater diffusion either through explicit customer communication or by the nature of their technology offerings.

We contribute to the literature on the distributional effects of environmental policy by evaluating utility consumers' access to clean energy. Despite growing evidence that the distributional effects of policy can play a central role in firms' adoption decision, it is less clear to what extent policy prescriptions affect utilities' efforts to make new energy technologies accessible to consumers. First, the impact of policies depends on their effect on disposable consumer income and utilities' bottom line. For example, LMI households may be excluded from solar benefits due to the cost of solar power. Similarly, the prevalence of high-income households may inform a utility's technology offerings, *i.e.*, the CSP solar panel ownership arrangement. Second, the redistributive effects of certain policies, e.g., deregulating access to technology choice, may trickle down to households depending on their purchasing power. For example, retail choice market and solar incentives may create mixed results emphasizing the importance of crafting policies without unintended consequences of disproportionally isolating LMI households.

The empirical findings of this paper suggest that electric utilities are more likely to support LMI accessibility to their CSP in the presence of policy prescription if their customer base is greatly LMI households. Specifically, policy interventions such as solar incentives or competitive markets where consumers have electricity provider choice promote LMI accessibility to CSPs, especially in markets with more LMI households. However, this result does not hold for customer-sited rooftop solar where mostly higher income households enjoy access to solar. Lastly, subscription-based access to solar for LMI households is higher in the presence of retail choice markets than traditional monopoly-like electricity markets where access is greatly a function of higher consumer income.

2. Literature review

The value of electricity as a critical infrastructure system cannot be overemphasized. The essential service nature of electricity supply is crucial to much of the world's functioning because it is a necessity for modern life particularly in regions where it is very cold or hot. For example, electricity supply is a United Nations Sustainable Development Goal that has impact on at least ten others amongst the 17 goals (Elavarasan et al., 2021). Understanding the growth of electricity supply with its sources is important especially in the context of the policy impacts on its transition into sustainable equivalents. Thus, the literature review draws from two strands of extant research: the distributional impact of environmental policy and research on sustainability transitions.

2.1. Distributional impact of policy on energy equity

Fuel poverty, *i.e.*, not being able to afford sufficient energy services to meet basic needs, has considerable social impact (Roberts, 2008). High fuel prices combined with low consumer incomes require policy interventions such as income-supporting subsidies for affordable energy access. Yet, many clean energy policies are flawed by an uneven distribution of economic opportunity and financial burden. Generally, policymakers have focused on the efficiency of clean energy policies spurring the argument that the next generation of polices should incorporate equity as first-order consideration in policy design and implementation (Shittu and Santos, 2021). Equity offers a more reliable metric for distributional impacts than the many competing, normatively charged notions of fairness that currently dominate public discussion (Mormann, 2019). The clean energy policies today create winners and losers not only across competing technologies but also among ratepayers and stakeholders. Renewable energy tax incentives have benefitted profitable corporations and renewable portfolio standards require such high levels of market expertise and financial acumen that they prove similarly exclusive (Liscow and Karpilow, 2017).

At the crux of a recent study is the best way to deploy solar energy to maximize clean energy growth while equitably sharing its benefits. The study examines the effect of design decisions on access to solar and the equity of cost and benefit sharing under the lens of how different U.S. states and utilities have designed such programs (Chan et al., 2017). Large-scale renewable projects, despite their environmental benefits, often have the unintended consequence of harming a community if the benefits are inequitably distributed (Yenneti and Day, 2016). A proposed solution is cross-subsidization for solar energy programs to achieve energy justice (Dolter and Martin, 2018; Baker et al., 2021). Yet, the distributional impacts of decentralized renewable electricity generation entail significant trade-offs between cost efficiency and regionally equitable allocations inciting the need for policies aimed at mitigating disparities (Sasse and Trutnevyte 2019). The focus on income disparities and energy access, incentivized by carbon pricing, shows that the welfare implications may be as significant as the inequity (Cronin et al., 2019).

There is ample reason for policymakers' concerns about distributional impacts with LMI households' energy expenditure being proportionally higher. Studies have shown that even within income groups, energy costs can vary widely (Deryugina et al., 2019). Thus, the multi-objective approach for policymakers is to reduce energy use while simultaneously preventing the unintended redistribution effects (Grainger, 2012). The equity-efficiency trade-off might support the adoption of less efficient policies just as policymakers tend to favor mandates because of their distributional and efficiency consequences (Fullerton, 2011). A recent survey shows that environmental policies can be regressive and suggests that revenues from certain policy instruments might help address the imbalance while suggesting that the distribution of environmental policy benefits (Holland et al., 2019) requires spatially disaggregated studies that capture the policy's spatial and socioeconomic impacts (Bento, 2013). For example, estimates of the pollution-reduction benefits of electric car subsidies across low- and high-income census tracts magnify inequity (Holland et al., 2019). This inequity is further corroborated by electric vehicle subsidies benefiting mostly rich people (Borenstein and Davis, 2016).

The increasing adoption of solar PVs has been accompanied by some regressive impacts that have led to a significant scale back of feed-in tariff policies in most jurisdictions in Australia (T. Nelson, Simshauser, and Kelley, 2011). In a related examination, the 'net' feed-in tariff in Queensland was found to be a regressive form of taxation. The extended impact is a *merit order effect* where price suppression due to the installation of significant renewable capacity has been found not to be welfare-enhancing (T. Nelson, Simshauser, and Nelson, 2012). The effect of poorly designed policies have exacerbated customer hardship. Electricity tariff structures have to replace flat prices and monthly billing with the use of smart meters and time-of-use pricing to ameliorate the incidence of hardship (Simshauser and Nelson, 2012).

Electric utilities operate either in retail electricity choice markets or traditional regulated retail electricity markets.[1] In retail choice markets, customers can often choose and switch electricity providers, and electricity providers may face opportunities for differentiation (Delmas et al., 2007). We explore how such policy environment relates to consumer accessibility of solar energy.

2.2. Incumbents' deployment of niche innovations in the sustainability transition literature

Research on sustainability transitions discusses how innovation, such as solar energy, develop in policy-protected spaces before they enter socio-technical regimes dominated by incumbents, a process that occurs against the backdrop of institutions, regulation, and policy facilitating diffusion (Schot and Geels, 2007). By facilitating innovation and affecting firms' actions, policies can drive sustainability transitions (Turnheim and Geels, 2013). Policy changes and policy mixes, whether layering or replacement of policies, affect the speed of sustainability transitions (Lindberg and Markard, 2019). However, less evidence exists for how policies affect customer accessibility to utilities' renewable energy offerings. For example, state-level financial incentives exist for the diffusion of distributed solar on the demand side such as rebates, loans, tax incentives, or grants. Furthermore, net metering policies[2] make utility customers' solar panel investments financially attractive (Smith et al., 2018), and thus are instrumental in the diffusion of distributed solar in the U.S., yet whether such benefits are skewed toward richer customers has been less studied.

New business models may help firms deploy innovation (Markard et al., 2012) that ensures consumer accessibility. Prior research highlights that incumbent firms play an important role in diffusing an innovation among their customer base (Berggren et al., 2015; Weigelt et al., 2021; Steen and Weaver, 2017). Yet, incumbent firms' established cognitive routines (R. R. Nelson and Winter 1982) and existing supplier and buyer networks may present rigidities (Leonard-Barton, 1992) when innovating. New business models such as community solar programs (CSPs) may require novel economic exchange processes and activities. At the same time, CSPs may present opportunities for utilities to remain relevant into the future and avoid the utility death spiral when too many consumers generate their own electricity and opt out of utility-provided services. The challenges associated with a new business model may be especially pronounced when ensuring accessibility to all customers.

A business model is a system of interconnected organizational activities performed to create and capture value (Massa et al., 2017). During sustainability transitions new business models are refined as their economic viability is tested (Santos and Eisenhardt, 2009). As a result, variances in the customer interfaces of firms deploying an innovation are likely. For example, customers can participate in utility-sponsored community solar programs by either purchasing/owning solar panels up-front, or by a monthly subscription contract for solar panels that can last 15–20 years. In return, customers receive credit on their monthly bill for the electricity their panels generate. Customer base income and policies likely play a role in utilities' choices.

Community solar programs provide customers who rent, live in a condo, have a shaded roof, or limited financial resources with accessibility to solar (Peters et al., 2018), but vary in the extent to which they explicitly target LMI customers as participants. Social motivations, cost savings, customer demand, and environmental sustainability may be drivers of community solar (Coughlin et al., 2011) that provides a substitute to individual customer rooftop solar installations, another form of distributed solar. Distributed solar is a radical shift from the traditional utility business model of remote, large-scale electricity generation from fossil fuels, and more recently wind and solar, that requires transmission and distribution lines to reach customers (Joskow, 2005). Utilities associate this shift to distributed solar with a utility death spiral. Distributed solar is small-scale, and customer-sited behind the meter, at the place of consumption (Gaul and Carley, 2012).

Evidently, prior research has shown how policies can eliminate participation hurdles in solar. However, it is yet to be seen to what extent utilities engage in efforts to advance the potential for LMI participation. The examination that follows contributes to the effects of environmental policy through the lens of utilities' efforts to provide consumer access to clean energy that also includes LMI households. We study the customer-facing deployment of community solar using utility website information where a utility's website is a key conduit through which customers can learn about the community solar program, how it works, its benefits and costs, and how to sign up for community solar.

3. Methods

3.1. Data and sample

We collected primary data from 187 utility websites reviewed in spring 2020 and secondary data from the 2018 EIA-861 data file, EIA websites, and the DSIRE database.

We started the primary data collection using the National Renewable Energy Lab (NREL) community solar project (CSP) list for the United States as of spring 2018. This list identifies CSP name, city, U.S. state, utility service territory where the system is sited, the year the project was grid-connected and started servicing customers, and project size in kilowatts. We transformed the list of 543 CSPs into a list with utilities as the unit of analysis showing their number of CSPs. About 60% of utilities on our list had one CSP, about 18% had two CSPs, about 4.7% had 3 CSPs, about 8% had between 4 and 10 CSPs, and the remaining few utilities had more than 10 CSPs. The first CSP on the list went

[1] As of 2017, a total of 17 U.S. states and the District of Columbia had fully or partially restructured retail electricity markets, while the rest of the United States had regulated retail electricity markets where individual utilities enjoy a monopoly position in their customer markets (Joskow, 2005). States with restructured retail electricity markets are California, Connecticut, Delaware, Illinois, Massachusetts, Maryland, Maine, Michigan, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Texas, and Virginia. Retail electricity market restructurings occurred during the late 1990s, with the most recent being Virginia in 2007 (www.electricchoice.com/map-deregulated-energy-markets/).

[2] Net metering is a billing mechanism that credits customers with rooftop panels for the excess solar electricity they generate. By 2017, a total of 44 U.S. states had net metering.

operational in 2000 with the most recent ones operational in 2018. We identified whether a utility was investor-owned, an electric cooperative, a municipal utility, or a political subdivision. Subsequently, we identified each utility's website address and main landing page from where we started our website review. Except for two electric cooperatives that had merged, we were able to identify all the websites of utilities in the sample.

We matched utility names from the NREL community solar list with EIA identifying information to collect utility-specific archival information on firm and customer characteristics from the EIA database for 2018 to use a year lag for independent variables in the regression analysis. The dependent variable was measured in spring 2020. Due to missing variables, the sample of firms in the regression analyses dropped to 122, 132, and 144 firms, respectively.

Two graduate research assistants reviewed each utility's website looking for specific information as outlined in Section 3.2 below. One of the authors supervised the two graduate students and checked their data collection results. Fig. 1 shows a snapshot of the distribution of utilities covered by U.S. states.

3.2. Dependent variables

The study has three dependent variables. First, ***LMI accessibility*** captures whether the utility's website mentions making the CSP accessible to lower-middle income (LMI) households, thus being inclusive of LMI households in its CSP. The variable is dichotomous with 1 indicating LMI accessibility and zero otherwise. LMI households in the U.S. make between $32K-$54K in annual income (Snider, 2020). A total of 27 utility websites that were reviewed mentioned such accessibility. The breakdown was 14 electric Coops, 8 investor-owned utilities, and 5 municipalities as of spring 2020.

Second, ***utility*** support ***customer-owned rooftop solar*** captures whether the utility's website mentions support for customer-owned rooftop solar in the form of customer rooftop solar information, partnerships with rooftop installers and banks for financing, and general encouragement of customers to adopt rooftop solar. The variable is dichotomous with 1 indicating utilities that support customer-owned rooftop solar explicitly on their website, and zero otherwise.

Third, ***participation via ownership*** captures how the utility's customers can participate in the CSP. The variable is dichotomous with 1 indicating that customers participate by owning panels in the CSP and zero indicates that customers participate by subscribing to panels. The information was gathered from utility websites. For example, Cherryland Electric Cooperative in Michigan has a subscription participation model. Customers purchase a panel subscription to the utility's CSP and get a credit on their monthly bill for the solar panel's output. A panel subscription costs either $600 upfront or $10 a month over five years. The subscription lasts for 15 years but can be cancelled. Alternatively, utilities that offer participation via ownership ask their customers to either purchase panels upfront or purchase a panel but pay in monthly installments over several months. The customer is credited the output of the solar panel to their monthly utility bill.

3.3. Independent variables

The independent variables are archival and measured as of 2018 to create a lag of one full year to the dependent variables captured in the website review conducted in spring of 2020.

Customer base average income proxies the purchasing power of a utility's customers. The data was collected from the Statistics of Income Division of the Internal Revenue Service at the state level for 2018. Adjusted gross income information from 1040 tax return information is reported as totals at the county level for each U.S. state and matched with each utility's state(s) of operation. We divide the adjusted gross income at the state level by the number of 1040 returns filed to proxy the customer base average income at the consumer level for the U.S. state(s) that the utility operates in. We focus on this measure since utilities' often target CSPs for individual households.

We collected policy data from the Database on State Incentives for Renewables and Efficiency (DSIRE).

Age of RPS mandate is a continuous variable for the number of years since a Renewable Portfolio Standard (RPS) was established in a U.S. state. As of 2018, a total of 30 U.S. states in addition to the District of Columbia had RPS mandates.

Retail choice market is one if a utility operates in a U.S. state with restructured retail electricity markets where customers have electricity provider choice and zero if the utility operates in a traditional monopoly retail electricity market. As of 2016, 13 U.S. states (NY, DE, RI, IL, NH,

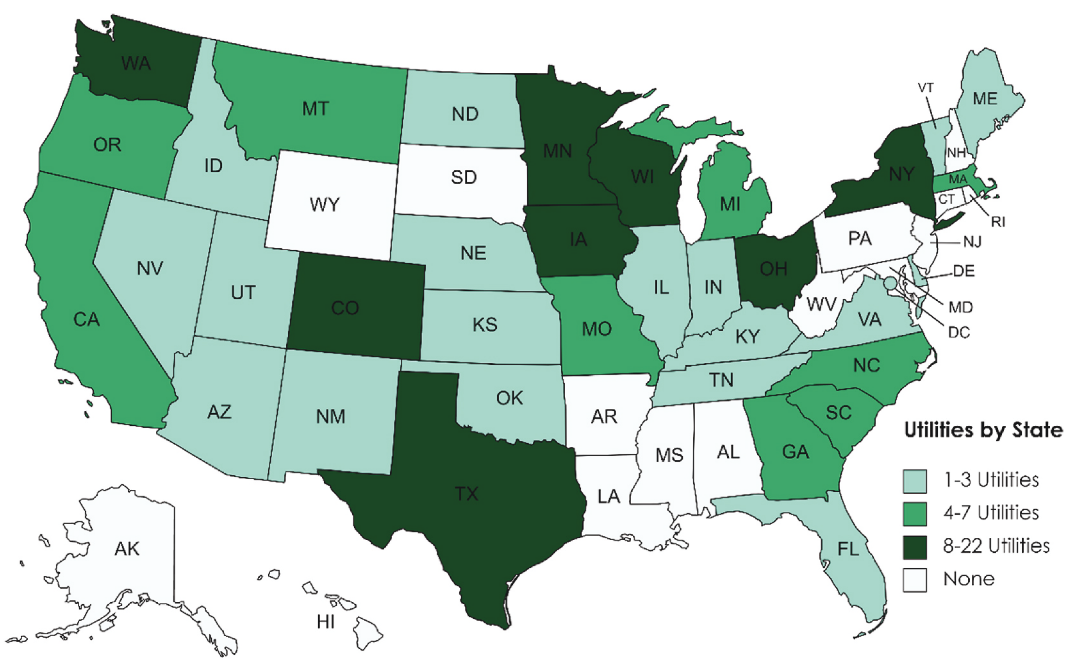

Fig. 1. Count of utilities with CSPs covered by state as at 2018.

MA, NJ, ME, MD, OH, CT, PA, TX) and D.C. had retail choice markets while 6 U.S. states (VA, OR, NV, MI, CA, MT) had limited retail choice (Heeter et al., 2017).

Solar incentives are the cumulative number of solar-related financial incentives that a U.S. state offers for the installation of solar power as of 2018. These incentives include rebates, loans, property tax incentives, leasing programs, personal tax credits, corporate tax deductions, grants, bonds, feed-in-tariffs green building incentives.

3.4. Control variables

We control for utility characteristics that may influence a utility's CSP deployment and approach to rooftop solar, and cluster for state effects. ***CSP intermediary*** is dichotomous and captures whether a utility used a third-party intermediary to aid with their CSP with 1 indicating any intermediaries mentioned on its website and zero otherwise. Some utilities mentioned working with several CSP intermediaries. Similarly, the variable ***Rooftop solar intermediary*** is dichotomous with 1 indicating that the utility works with a rooftop solar partner, and zero otherwise.

We use two dummy variables to capture the type of utility: ***electric cooperative*** and ***municipal utility*** with investor-owned utilities (IOUs) as reference category. While IOUs are public companies maximizing shareholder value, electric cooperatives are member-owned. Electric cooperatives and municipal utilities are smaller and more geographically limited than IOUs. While the median customer number for IOUs is around 400,000 customers, the median customer number is 2000 for electric cooperatives and 13,000 for municipal utilities as of 2016 (Warwick et al., 2016). Although IOUs serve around two-thirds of U.S. customers, they only represent about 6% of utilities. (American Public Power Association, 2018).

Percentage of residential customers is a utility's proportion in MW sales for electricity supplied to residential customers relative to total sales using data from the EIA-861 report. Customer segments are residential, industrial, and commercial. ***Net metering customers*** is the log of the number of net metering customers that are connected to a utility's distribution grid and captures the extent to which a utility's customers become prosumers, *i.e.* producers and consumers of electricity at the same time (Weigelt et al., 2021; Barna et al., 2020).

Net generation captures the proportion of electricity that a utility generates in-house relative to total electricity (sum of wholesale electricity purchases and in-house generated electricity). The variable captures the extent to which the utility relies on utility-scale self-generation which is a substitute to distributed electricity generation.

Fig. 2 presents espoused reasons/motivations for why a utility might deploy a CSP. ***Response to customer interest*** is one if it is mentioned as motivation for the CSP on the utility website and zero otherwise. ***Doing good*** is one if it is mentioned as motivation for the CSP and zero otherwise, and finally ***broader renewable energy strategy*** is one if it is mentioned that the CSP is part of a broader renewable energy strategy as indicated by other solar and wind activities (utility-scale or Power Purchase Agreements) mentioned online. These reasons are not mutually exclusive.

Age of CSP is continuous and captures the number of years that a utility's CSP has been operational, using information from the NREL CSP list. A utility that launched its CSP in 2015 may have a website that has evolved to a different extent than a utility launching its CSP in 2019.

3.5. Descriptive statistics

Table 1 provides variable means, standard deviations, and correlations. We estimated the variance inflation factors (VIF) for the variables and each model. We found a range from 1.4 to 1.58 indicating the absence of multicollinearity. VIFs greater than 10 indicate model weakness due to multicollinearity (Greene, 2003).

3.6. Estimation method

We conduct logistic regression to estimate the relationship between customer base average income, policy, and likelihood of the utility supporting accessibility to solar electricity. We estimate three separate models: the likelihood of LMI accessibility to utility CSPs, the likelihood that the utility emphasizes the benefits of customer rooftop solar, and the likelihood of CSP ownership models. We cluster by state to control for differences across U.S. states that may influence consumer accessibility to solar.

4. Results

4.1. Main findings: LMI CSP accessibility

Model 1 in Table 2 shows the control variables. The negative coefficient of percentage of residential customers (β = -7.076, $p < 0.01$) indicates that more residential utility sales reduce the likelihood that a

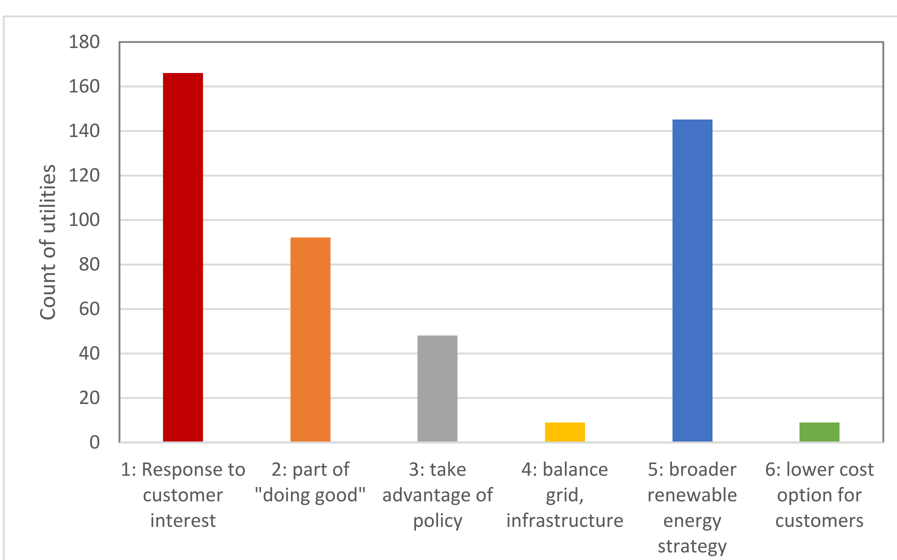

Fig. 2. Espoused reasons for having a CSP.

Table 1
Descriptive statistics: Means and correlation matrix.

	Variable Name	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	LMI accessibility of CSP	0.17	0.38	0.00	1.00	1.000																			
2	Rooftop solar support	0.59	0.49	0.00	1.00	−0.235	1.000																		
3	CSP Ownership Participation	0.55	0.50	0.00	1.00	−0.338	0.165	1.000																	
4	CSP intermediary	0.27	0.45	0.00	1.00	0.176	0.088	−0.315	1.000																
5	Rooftop solar intermediary	0.18	0.38	0.00	1.00	0.041	0.274	−0.031	0.171	1.000															
6	Customer base average income	66.23	8.52	51.29	88.43	0.169	0.299	−0.095	0.170	0.072	1.000														
7	Customer base <50k average income	19.74	0.83	17.36	21.14	−0.119	0.018	−0.027	−0.161	−0.145	−0.097	1.000													
8	Customer base <75k average income	27.69	1.20	25.14	29.72	−0.010	0.129	0.028	−0.090	−0.092	0.277	0.834	1.000												
9	Net metering customers	5.15	2.49	0.69	12.89	0.124	0.079	−0.132	0.227	−0.033	0.350	−0.425	−0.296	1.000											
10	Percentage of residential customers	0.51	0.20	0.01	0.89	−0.208	−0.045	0.061	−0.105	−0.068	−0.304	0.176	−0.020	−0.261	1.000										
11	Broader renewable energy strategy	0.62	0.49	0.00	1.00	−0.124	0.423	0.071	0.025	0.213	0.249	0.129	0.275	0.103	−0.176	1.000									
12	Cooperative electric utility	0.58	0.49	0.00	1.00	−0.103	0.008	0.168	−0.218	−0.061	−0.330	0.227	0.084	−0.479	0.568	−0.162	1.000								
13	Municipal electric utility	0.15	0.36	0.00	1.00	0.016	−0.043	−0.045	−0.045	0.007	0.155	−0.016	0.014	−0.120	−0.307	0.056	−0.508	1.000							
14	Age of CSP	4.47	2.07	1.00	11.00	0.353	−0.138	−0.051	0.054	0.032	−0.018	−0.055	−0.072	0.160	−0.084	−0.003	0.077	0.000	1.000						
15	Net generation	0.44	0.50	0.00	1.00	0.122	0.070	−0.140	0.126	0.040	0.319	−0.198	−0.052	0.339	−0.351	0.176	−0.554	0.290	0.135	1.000					
16	Part of "doing good" sustainability	0.50	0.50	0.00	1.00	0.277	−0.006	−0.229	0.047	−0.056	0.255	−0.150	0.026	0.174	−0.184	0.091	−0.300	0.234	0.001	0.227	1.000				
17	Response to customer interest	0.85	0.36	0.00	1.00	−0.246	0.206	0.090	−0.042	0.096	−0.082	−0.057	−0.077	−0.038	−0.113	0.033	−0.203	0.130	−0.247	0.063	0.117	1.000			
18	Age of RPS mandate	13.78	8.77	0.00	37.00	0.036	0.017	0.166	−0.015	−0.005	0.212	0.190	0.362	0.027	−0.130	0.113	−0.033	0.015	−0.051	0.137	0.028	−0.169	1.000		
19	Retail choice market	0.34	0.47	0.00	1.00	0.071	0.080	−0.068	0.166	−0.095	0.251	−0.376	−0.308	0.358	−0.079	−0.019	−0.273	0.067	−0.156	0.219	0.056	0.016	0.174	1.000	
20	Solar incentives	4.56	3.38	0.00	12.00	0.06	0.16	−0.08	−0.04	0.06	0.61	−0.01	0.08	0.27	−0.08	0.11	−0.12	0.10	−0.02	0.14	0.04	−0.02	0.20	0.08	1.000

Table 2
Likelihood that a utility supports LMI accessibility to its CSP.

DV: LMI accessibility to CSP	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	1.060	0.150	−165.0*	−7.483	−14.83
	(2.113)	(1.687)	(83.65)	(5.219)	(10.59)
CSP intermediary	−1.347	−1.866	−1.744	−2.095	−1.450
	(0.727)	(1.017)	(1.284)	(1.221)	(1.064)
Net metering customers	−0.158	−0.435*	−0.423*	−0.453*	−0.471*
	(0.174)	(0.211)	(0.192)	(0.191)	(0.198)
Percentage of residential customers	−7.076**	−7.825**	−9.872*	−8.443*	−8.327*
	(2.390)	(2.912)	(4.391)	(3.662)	(3.480)
Broader renewable energy strategy	−1.695	−2.159	−2.388	−2.044	−2.365
	(0.935)	(1.323)	(1.385)	(1.444)	(1.312)
Cooperative electric utility	1.184	2.698	2.314	2.999	1.900
	(1.073)	(1.555)	(1.597)	(1.791)	(1.419)
Municipal electric utility	−0.352	−0.0992	−1.249	0.136	−0.448
	(1.362)	(1.554)	(1.203)	(1.446)	(1.241)
Age of CSP	0.395*	0.485*	0.614*	0.571*	0.549*
	(0.167)	(0.238)	(0.264)	(0.277)	(0.227)
Net generation	0.325	1.648	1.414	1.651	0.825
	(0.821)	(1.086)	(1.018)	(1.038)	(1.224)
Part of "doing good" sustainability	2.151	2.090	1.960	2.303*	2.034
	(1.152)	(1.101)	(1.130)	(1.166)	(1.100)
Response to customer interest	−2.661*	−2.926**	−3.336***	−2.961**	−2.806**
	(1.037)	(0.975)	(0.984)	(1.016)	(1.006)
Age of RPS mandate		−0.0338	−0.0589	−0.0414	−0.0324
		(0.0272)	(0.0373)	(0.0288)	(0.0316)
Retail choice market		0.156	0.661	15.38*	0.341
		(0.876)	(0.844)	(7.535)	(1.035)
Solar incentives		0.258*	0.182	0.225	2.958
		(0.130)	(0.127)	(0.147)	(1.576)
Customer base average income			5.001*	0.111	0.256
			(2.508)	(0.0774)	(0.177)
Customer base average income squared			−0.0371*		
			(0.0186)		
Customer base average income X Retail choice market				−0.227*	
				(0.114)	
Customer base average income X Solar incentives					−0.0426
					(0.0259)
Wald chi2	110.61***	174.47***	168.04***	215.68***	146.59***
Number of observations	124	122	122	122	122

Standard errors in parentheses * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$″.
Standard errors adjusted for 31 state clusters.

utility promotes CSP access among LMI customers. The coefficient for a utility's sustainability (or doing good) motivation is positive (β = 2.151), while the coefficient for utility's motivation driven by customer CSP interest is negative (β = -2.661, $p < 0.05$). This result implies that a utility's effort at making their CSP accessible to LMI customers is more informed by its sustainability motivation than by customer interest in community solar. A reason may be that greater customer interest yields a sufficient number of higher income customers signing up for CSP. As the age of a utility's CSP increases (β = 0.395, $p < 0.05$), the more likely access is promoted to LMI customers. It may be that utilities first try to recoup their investment with customers able to pay their full share prior to extending CSP access to LMI customers that might require subsidies. The coefficients for the utility ownership dummies are not significant, indicating a lack of differences in LMI accessibility between different utility types.

4.1.1. *Policy effects*

Model 2 shows the solar incentives effect: Although financial solar incentives offered at the state level range from rebates, loans, property tax incentives, to feed-in-tariffs green building incentives, the multiplicity of these options might explain their significance (β = 0.258, $p < 0.05$) with LMI accessibility. The coefficients for retail choice markets and age of RPS are not significant, maybe because the dependent variable captures community solar accessibility to a utility's customer base rather than solar adoption among utilities, which is the focus of RPS.

4.1.2. *Customer base income effect*

In Model 3, the effect of customer base average income is positive (β = 5.001, $p < 0.05$) while the quadratic income effect is negative (β = -0.0371, $p < 0.05$). These two results underline an important observation. As the average customer income increases, the more likely the utility is to promote CSP access to LMI customers, but this relationship only occurs up to a point beyond which higher income levels lead to diminishing LMI customer accessibility. The finding indicates an interesting paradox: utilities with richer customers, on average, tend to also include LMI customers in their CSP while utilities whose customer base has a lower average income, and thus might benefit in particular from LMI-sponsored accessibility, might be less likely to receive such access.

The direct effect of customer base average income alone was not significant in predicting the likelihood of utilities supporting LMI accessibility to their CSP.

4.1.3. *Interaction: policy and customer base income effect*

In Model 4, the interaction of customer base average income with the presence of retail choice markets is negative (β = -0.227, $p < 0.05$), implying that the average income effect varies due to market competitiveness. Given that logit models are non-linear we cannot directly assess the interaction simply by looking at the coefficient but need to graph the marginal effects in Fig. 3.

In the presence of retail choice (the broken line), the likelihood that a utility emphasizes LMI accessibility to community solar is higher, the lower the average income. In contrast, in the absence of retail choice (the continuous line), LMI accessibility to community solar is higher, the

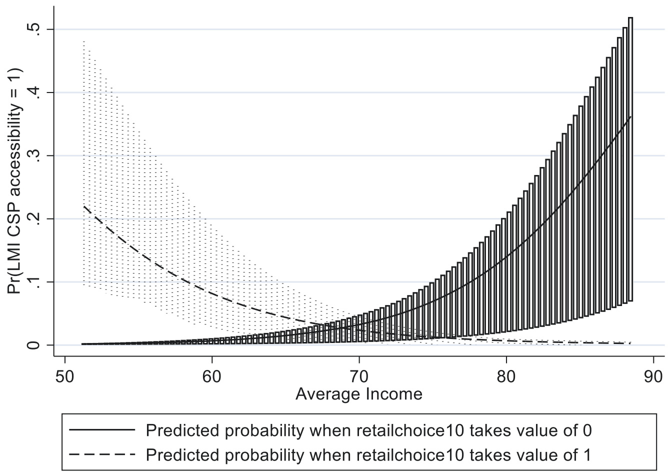

Fig. 3. The interaction of average customer base income with retail choice in a competitive market.

higher the average customer income. The finding shows that utilities are more likely to support LMI accessibility in traditional retail markets when they have a higher average income customer base. In contrast, utilities are more likely to support LMI accessibility in the presence of a lower average income customer base in competitive retail markets.

Model 5 shows the negative interaction of solar incentives with average customer base income (β = -0.0426). We graph the marginal effects in Fig. 4 in relation to LMI accessibility.

Fig. 4 shows that the presence of solar incentives (broken line) promotes LMI accessibility in the presence of a lower average income customer base, while LMI accessibility is more likely in the presence of a higher average income customer base in the absence of solar incentives (continuous line). Thus, the interaction graph shows that solar incentives are instrumental in increasing the likelihood that utilities make their CSP accessible to LMI customers.

Overall, the interaction findings show that utilities are more likely to support LMI accessibility to CSPs in the presence of solar incentives or in a competitive market if they have a lower average income customer base. Policy tools such as solar incentives and a more competitive market help in increasing LMI accessibility to CSP in the presence of a lower income customer base. In monopoly electricity retail markets or in the absence of solar incentives, the likelihood that a utility supports LMI accessibility increases with a higher average income customer base. In sum, both policy and customer base income play a role in whether a utility promotes LMI accessibility in its CSP online.

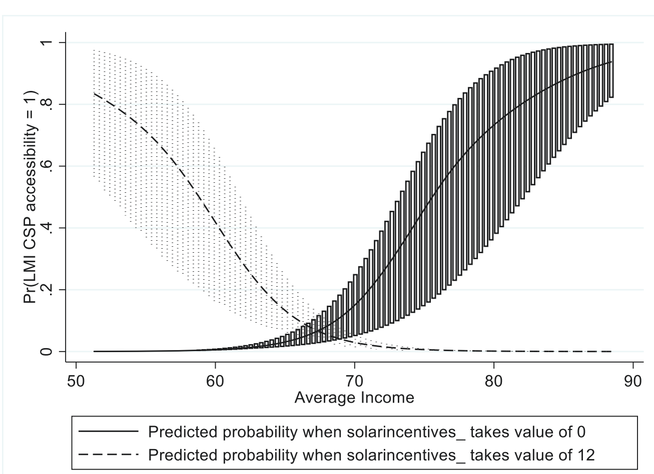

Fig. 4. The interaction of average customer base income with solar incentives.

Other controls of significance are a utility's customers who net meter an installed rooftop solar on their site, implying that more net metering customers decrease the likelihood that their utility supports LMI accessibility for their CSP. A potential reason may be that utilities with more net metering customers may feel threatened regarding their revenue source (Botelho et al., 2021). Under perceived threat, electric utilities may be less inclined to support LMI accessibility initiatives. In fact, this echoes the energy market death spiral where the investment megacycle by utilities in solar PV is leading to electricity tariff increases and worsening customer hardship (Simshauser and Nelson, 2012).

4.2. Main findings: Rooftop solar

Table 3 shows the likelihood of supporting rooftop solar on the utility website, e.g., informing customers of rooftop solar installation opportunities. Model 1 introduces the controls: Motivation driven by customer interest has a positive effect (β = 2.091, $p < 0.01$). Furthermore, utilities partnering with a solar panel installer are more likely to support rooftop solar among their customer base. Scope of renewable activities in solar and wind has a positive effect indicating that utilities with utility-scale wind or solar are more likely to support rooftop solar.

Our findings imply that electric coops are more supportive of customer-sited rooftop solar installations than IOUs, as indicated by the dummy capturing utility type. A reason may be that electric coops are owned by their members and smaller than IOUs, which, in turn, may make them more responsive to the demands of their customer base. In contrast, municipal utilities and IOUs do not seem to differ in their support for customer rooftop solar.

4.2.1. Policy effects

Model 2 shows that the coefficient for retail choice markets is positive (β = 1.373, $p < 0.05$). Utilities in competitive retail markets are more likely to support customer-sited rooftop solar than utilities in monopoly-like traditional markets. Neither solar incentives nor age of

Table 3
Likelihood that a utility supports customer-owned rooftop solar installation.

DV: rooftop solar support	Model 1	Model 2	Model 3
Constant	−3.743*	−4.849**	−16.18**
	(1.548)	(1.587)	(5.963)
Rooftop solar intermediary	2.497**	3.189**	3.643*
	(0.952)	(1.152)	(1.467)
Percentage of residential customers	−0.0255	−0.0427	1.087
	(0.949)	(0.985)	(0.880)
Broader renewable energy strategy	2.046***	2.181***	2.083***
	(0.553)	(0.565)	(0.629)
Cooperative electric utility	1.274	1.809*	1.785*
	(0.703)	(0.758)	(0.776)
Municipal electric utility	−0.208	−0.156	−0.768
	(0.815)	(0.850)	(1.059)
Age of CSP	−0.0490	−0.0439	−0.0254
	(0.0732)	(0.0644)	(0.0688)
Net generation	0.980	1.289*	1.204
	(0.629)	(0.639)	(0.645)
Part of "doing good" sustainability	0.00307	0.0582	−0.463
	(0.447)	(0.432)	(0.529)
Response to customer interest	2.091**	2.161**	2.618**
	(0.746)	(0.780)	(0.826)
Age of RPS mandate		−0.0313	−0.0257
		(0.0336)	(0.0460)
Retail choice market		1.373*	1.625
		(0.692)	(0.832)
Solar incentives		0.0793	−0.121
		(0.112)	(0.116)
Customer base average income			0.177*
			(0.0812)
Wald chi2	26.25***	38.72***	45.36***
Number of observations	148	146	146

Standard errors in parentheses * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.
Standard errors adjusted for 32 state clusters.

RPS are significant.

4.2.2. Customer base income effect

Model 3 in Table 3 shows that customer base average income is positive (β = 0.177, $p < 0.05$), but does not have a significant curvilinear effect. The higher the customer average income, the higher utility support for rooftop solar. A reason for this finding may be that customer-sited rooftop installations are not cheap and therefore require wealthy customers to either self-finance solar panels or qualify for third-party financing.

Integrating these results lead to the remark that the higher the average customer base income becomes, the higher is utility support for rooftop solar (Table 3) and CSP (Table 2). We did not find support for interaction effects between utility customer base average income and policy effects in predicting the likelihood of a utility supporting customer-sited rooftop solar.

4.3. Main findings: Panel ownership vs. subscription model

Table 4 examines the approaches a utility uses to offer its customers CSP participation through different ownership structures (ownership of solar panels or subscription). All models show that when a utility uses a third-party intermediary to aid in CSP deployment, customers are more likely to have the subscription option. The coefficient for third-party intermediary is negative and significant in all models.

4.3.1. Policy effects

Model 2 shows that the age of RPS is positive (β = 0.0721, $p < 0.01$) demonstrating the support of RPS stability for utilities offering their customers CSP panel ownership. Perhaps the ownership decision is dominant because policy age implies an absence of repeals or ambivalence in its promulgation. Policy persistence appears to enhance customer engagement through panel ownership. Model 3 shows that solar incentives are negative (β = -0.171, $p < 0.05$) underscoring how incentives support subscriptions to solar. Distilling these results shows the direct relevance of policy particularly highlighting how the longer RPS (a command and control policy) is established, the more likely utilities promote panel ownership for CSP customers. The more solar incentives (a market policy), the more likely utilities promote a subscription model for their CSP. The retail choice market effect is not significant.

Table 4
Likelihood that a utility only has the ownership option for its CSP participation.

DV: ownership option for CSP participation	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Constant	0.0561	−0.608	−4.082	22.52*	12.95	−13.36	−15.62	44.73*	43.66*
	(1.209)	(1.292)	(2.653)	(8.788)	(9.113)	(14.33)	(10.45)	(18.31)	(19.19)
CSP intermediary	−1.920*	−1.869**	−1.966**	−1.921***	−1.780**	−2.025***	−2.031***	−1.994**	−1.953**
	(0.772)	(0.679)	(0.653)	(0.566)	(0.637)	(0.600)	(0.594)	(0.609)	(0.649)
Percentage of residential customers	−0.471	−0.0654	0.236	0.438	−0.0738	0.199	0.621	0.0951	−0.561
	(0.954)	(1.096)	(1.162)	(1.205)	(1.095)	(1.336)	(1.147)	(1.141)	(1.132)
Broader renewable energy strategy	0.318	0.213	0.0796	0.768	0.666	0.872*	0.740	0.786	0.817
	(0.447)	(0.430)	(0.462)	(0.417)	(0.467)	(0.407)	(0.448)	(0.440)	(0.425)
Cooperative electric utility	0.242	0.175	0.139	0.450	0.465	0.638	0.362	0.227	0.421
	(0.645)	(0.755)	(0.737)	(0.641)	(0.675)	(0.676)	(0.650)	(0.679)	(0.722)
Municipal electric utility	0.238	0.283	0.123	0.875	0.732	1.096*	1.034	0.574	0.643
	(0.651)	(0.694)	(0.716)	(0.536)	(0.567)	(0.535)	(0.632)	(0.555)	(0.581)
Age of CSP	0.0399	0.0514	0.0567	0.0552	0.0350	0.0483	0.0601	0.0803	0.0599
	(0.0880)	(0.0872)	(0.0888)	(0.0867)	(0.0851)	(0.0819)	(0.0826)	(0.0901)	(0.0884)
Net generation	0.0895	0.0140	−0.0966	−0.503	−0.134	−0.219	−0.123	−0.677	−0.334
	(0.547)	(0.657)	(0.661)	(0.587)	(0.584)	(0.637)	(0.647)	(0.640)	(0.622)
Part of "doing good" sustainability	−0.492	−0.601	−0.810	−0.923*	−0.611	−0.809	−0.813*	−1.148**	−0.905
	(0.411)	(0.412)	(0.451)	(0.439)	(0.416)	(0.443)	(0.414)	(0.429)	(0.485)
Response to customer interest	0.763	0.940	1.043	1.369	1.109	1.333	1.374	1.482	1.283
	(0.713)	(0.736)	(0.736)	(0.762)	(0.753)	(0.763)	(0.749)	(0.801)	(0.730)
Age of RPS mandate		0.0721**	0.0724***	0.103***	0.0996**	0.0619*	0.0432	0.119***	0.141**
		(0.0219)	(0.0211)	(0.0284)	(0.0320)	(0.0300)	(0.0358)	(0.0356)	(0.0479)
Retail choice market		−0.390	−0.377	−0.823	−0.772	48.93**	56.07**	−0.298	−0.277
		(0.533)	(0.513)	(0.512)	(0.524)	(18.01)	(19.54)	(0.565)	(0.559)
Solar incentives		−0.0935	−0.171*	−0.118	−0.0917	−0.197*	−0.220*	−5.131	−5.633*
		(0.0754)	(0.0751)	(0.0943)	(0.0916)	(0.0800)	(0.0972)	(2.913)	(2.779)
Customer base average income			0.0590						
			(0.0431)						
Customer base average income <50K category				−1.217**		0.611		−2.344*	
				(0.460)		(0.747)		(0.947)	
Customer base average income <75K category					−0.518		0.528		−1.656*
					(0.343)		(0.400)		(0.720)
Retail choice market X Customer base average income <50K category						−2.487**			
						(0.893)			
Retail choice market X Customer base average income <75K category							−2.044**		
							(0.702)		
Solar incentives X Customer base average income <50K category								0.254	
								(0.146)	
Solar incentives X Customer base average income <75K category									0.202*
									(0.101)
Wald chi2	10.05	28.57***	38.52***	47.70***	32.21***	171.77***	83.47***	59.95***	29.68***
Number of observations	134	132	132	132	132	132	132	132	132

Standard errors in parentheses * $p < 0.05$ **$p < 0.01$ ***$p < 0.001$″.
Standard errors adjusted for 30 state clusters.

4.3.2. Customer base income effect

In Model 4, the customer base average income grouping below $50,000 has a negative effect (β = -1.217, $p < 0.01$) indicating that as customer average income increases, so does the likelihood that a utility offers subscription access to its CSP. Model 5 shows these results to be consistent for customers with household incomes of $75,000 or less (β = -0.518). Contrasting these results with Model 3 where the average income (not demarcated by income categories) is not significant, we highlight that setting income boundaries helps to isolate LMI households, and thus, highlight the influence of their income bracket on the likelihood that a utility offers access to their CSP by subscription rather than only by ownership.

4.3.3. Interaction: policy and customer base income effect

Interacting the utility customer base average income with retail choice markets in Models 6 and 7 show that, independent of income categorization, the interactions are negative (β = -2.487; $p < 0.01$) and (β = -2.044; $p < 0.01$), for income brackets $50,000 and below, and $75,000 and below, respectively. We graph the marginal effects of the interaction in Figs. 5 and 6.

In Fig. 5 the interaction turns significant around 20 which is the 50% percentile for customer base average income less than $50,000. As customer average income increases, the likelihood of utilities offering only panel ownership in traditional, monopoly-like electricity retail markets increases. In contrast, in competitive electricity retail markets, utilities are more likely to offer subscription-based access to solar panels in CSPs, as customer average income increases. The interaction is not significant at the lower end of the customer average income group of less than $50,000.

Fig. 6 mirrors Fig. 5 for customer average income of less than $75,000. The interaction turns significant around 28 which falls between the 50% and 75% percentile for customer base average income in the less than $75,000 category.

In sum, the results show that subscription-based access to CSPs is more likely supported in retail choice than traditional monopoly-like markets as customer average income increases in the LMI customer groups. As LMI customers fall into the upper-end of the LMI category, they may increasingly have the disposable income to spend on renewable electricity. As customer income increases, the preference for 'being sustainable' my also increase among customers. Subscription-based models provide an affordable venue to access the benefits of CSPs. Offering affordability to customers may be more important for utilities in competitive markets where customers have electricity provider choice. In contrast in traditional monopoly-like markets, utilities are more likely

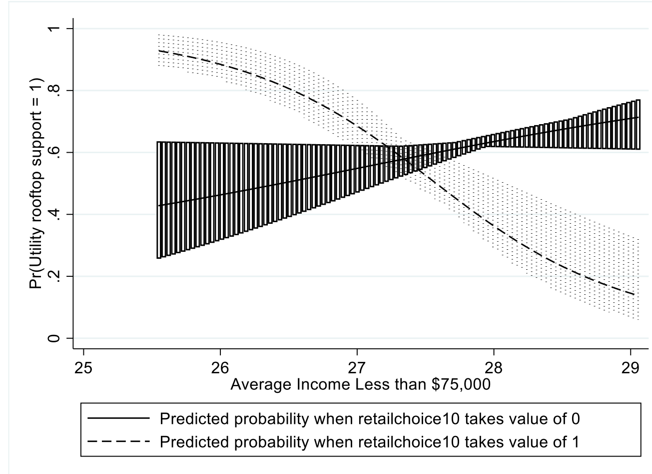

Fig. 6. Interaction of retail choice competition with average customer base income less than $75,000.

to offer solar panel ownership in CSPs, which requires a greater customer commitment and often a larger upfront financial sum. As a result, CSP accessibility declines.

The influence of capital outlays underlines the role that policy might play in rebalancing the distributional lopsidedness of consumer access to clean energy. We posit that the 'right' policy choices when integrated with access by subscription or panel ownership may indeed induce inclusion of LMI households. The propensity of policy to act as a lever for redistributive or equity effects is evident in retail choice competitive markets. The overarching value is the understanding that policy choices, when carefully crafted, may prevent unintended consequences of disproportionally isolating LMI households.

The interaction of customer average income, across the two income brackets, with solar incentives in Models 8 and 9 are positive (β = 0.254) and (β = 0.202, $p < 0.05$) for average income of $50,000 and $75,000, respectively. Figs. 7 and 8 show the marginal effects of these interactions.

Figs. 7 and 8 for the two LMI income brackets, respectively, mirror each other. The interaction in Fig. 7 is significant at the lower levels of customer average income below approximately $20,000 which is below the 50% percentile of customer average income less than $50,000. Fig. 7 shows that at lower levels of customer average income, the likelihood of utilities offering CSP subscription-based access increases in the presence

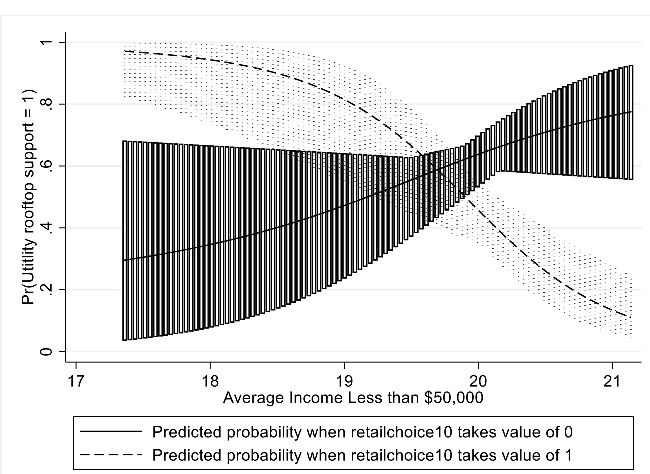

Fig. 5. Interaction of retail choice competition with average customer base income less than $50,000.

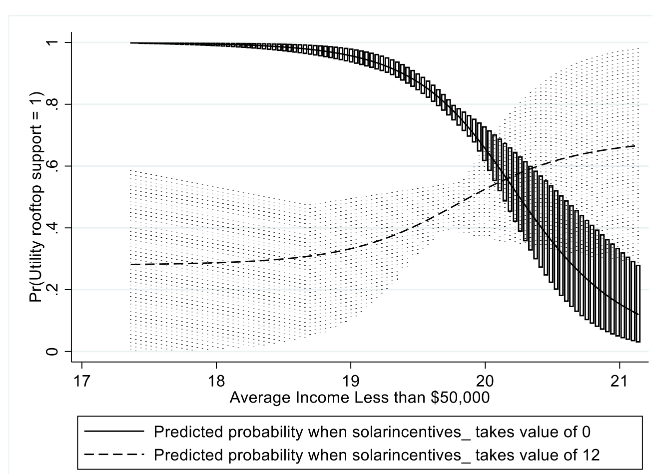

Fig. 7. Interaction of solar incentives with average customer base income less than $50,000.

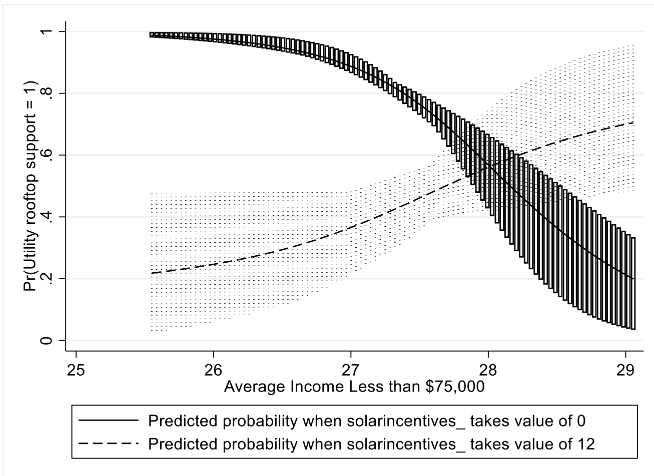

Fig. 8. Interaction of solar incentives with average customer base income less than $75,000.

of solar incentives. In contrast, in the absence of solar incentives, utilities are likely to offer ownership-based CSP access at lower customer average income. One could argue that offering CSP access via panel ownership forecloses solar benefits to LMI customers at the lower end of that income bracket. Fig. 8 mirrors the findings of Fig. 7 and shows significant values for customer average income below the 50% (around $27,875 in Fig. 8). In sum, the findings demonstrate the importance of solar incentives in promoting CSP accessibility via subscription, especially for LMI customers with lower average incomes.

4.4. The distribution of the average customer base income by dependent variable

In summary, the distribution around the average customer base income offers another lens of viewing the results in a manner that is reinforcing. We plotted boxplots for each of the dependent variables as a function of utilities' average customer base income. Fig. 9 shows the distribution of customer base average incomes by the utility's accessibility approach. The first two boxplots represent the distribution of utilities' average customer base incomes by utilities offering CSP accessibility to LMI households and utilities not offering LMI accessibility to their CSP, respectively. The boxplot shows that the median and average customer base incomes are higher for utilities offering LMI accessibility to their CSP. A similar pattern can be observed in the next pair of boxplots: The average customer base income range for utilities that do not offer rooftop solar support is smaller than for utilities that offer rooftop solar support. The last pair shows that panel subscription correlates with a slightly higher mean and median average customer base income than panel ownership.

5. Robustness tests

We estimated several robustness tests. We re-estimated the earlier Models 4 and 5 in Table 2, Model 3 in Table 3, and Models 6–9 in Table 4 without the constant terms to ascertain that our prior results stand (Bianco and Elena, 2009). The results are largely consistent with those in the main models where the constant term is a significant part of the predictors. We note that the discontinuous and nonlinear properties of the logistic regression model imply that the magnitude of the effects may not be inferred from the coefficients, but only the sign and statistical significance of the variables (Bowen, 2012).

6. Conclusion and policy implications

In this study we highlight the interplay of customer purchase power and policy for utilities' role in providing consumer accessibility to distributed solar. We focus on accessibility by LMI households to utility-sponsored CSPs, accessibility support for customer-sited solar, and CSP subscription-based accessibility. Consumer accessibility to sustainable offerings is key in the equitable diffusion of sustainability practices that enables inclusivity in participation across customer groups of varying income. Our findings across three accessibility points show that economics greatly relate to consumer accessibility in the absence of policy, and that policy plays a crucial role in increasing inclusivity of access to solar electricity for LMI households.

The paradox is that LMI accessibility is more likely emphasized on the websites of utilities with higher income customers. Yet, lower customer income tends to be negatively related to LMI accessibility.

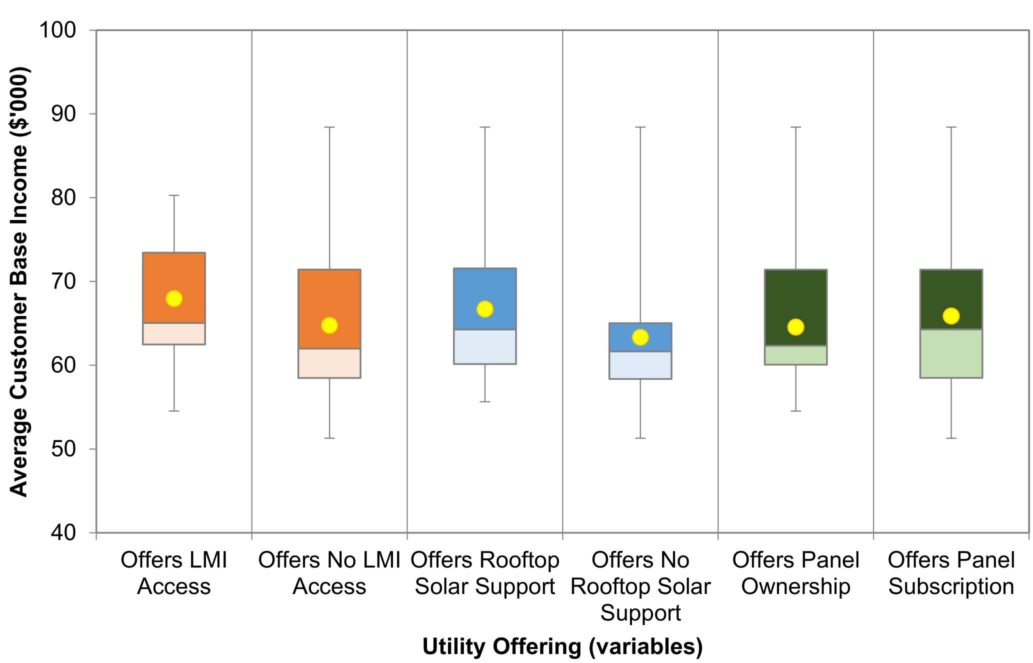

Fig. 9. Distribution of average customer base income by utility offerings for accessibility.

There seems to be a sweet spot for LMI accessibility to CSPs where a utility's customer base has sufficient income to pay, yet less than needed for customers to install solar panels on their own.

Our findings support that policy matters two-fold: First, solar incentives are instrumental in making utility-sponsored CSPs accessible to LMI households, especially the lower customer income. Second, the retail market competitive situation impacts LMI accessibility based on customer average income. In traditional markets LMI accessibility seems linked to higher customer income. In contrast, in competitive markets LMI accessibility seems more likely with lower customer income. Both retail choice and solar incentives help promote LMI accessibility to CSPs in the presence of lower income customers.

Regarding rooftop solar, we find that utilities are more likely to support customer solar panels in competitive than traditional electric retail markets, and if customer base income is higher. Customers installing solar panels on their own rooftops tend to be wealthier. Therefore, utilities may support solar rooftop installations if their customer base can afford such and switch electricity providers. However, the sustainability benefit of CSPs is to provide solar electricity access to customers who cannot afford their own solar panels. Our findings show that customer base purchasing power matters in whether utilities promote their CSPs to include LMI customers. Higher customer average income helps with inclusivity and CSPs accessibility to LMI households.

CSPs with subscriptions arguably have greater consumer accessibility than CSPs requiring panel ownership. We find strong policy effects: At lower customer income, subscription access was more likely with solar incentives. At higher levels of customer income, subscription models were more likely in competitive retail markets and ownership models in traditional retail markets.

Theoretically, we contribute to distributional theory of environmental policy by shedding light on the intricacies that exist when focusing on LMI households' access to sustainable energy. To the best of our knowledge, the interplay between policy and customer purchasing power and equitable solar electricity accessibility for consumers, as provided, and emphasized by utilities, has not been evaluated and investigated. Although different environmental policies exist, several of them have nuances that may create consumer adoption hesitancy. Overcoming consumer adoption hesitancy requires that policy prescriptions entail equitable considerations that ensure that corporations making sustainable offerings available with an eye toward equitable customer access.

Policy implications: Policies have supported grassroots marketing campaigns such as the "Solarize Program" aimed at lowering costs and increasing adoption (Gillingham and Bollinger, 2017). Notable enactments targeting LMIs include: (i) Low Income Home Energy Assistance Programs (LIHEAP) to provide eligible households with support for their heating and cooling bill payment and energy crisis assistance (Murray and Mills, 2014); (ii) the Weatherization Assistance Program (WAP) that supports low-income, senior citizens, and disabled residents to reduce their utility bills by making their homes more energy efficient with upgrades such as insulation and air sealing (Fowlie et al., 2018).

Our policy findings show that democratizing or approaching greater equity in renewable energy access requires a careful set of policy choices that will not alienate LMI households. Policies need to be crafted to ensure that they do not run the risk of creating unequal access to renewable energy. Policies in sustainability transitions need to ensure that they are not creating a sustainable future for the 'haves' that excludes the 'have-nots' who do not have the financial means to access sustainable energy. Policymakers should be mindful of the type of policy that is enacted or promulgated. We can see how incentives and retail choice support solar access but do so more for some customer groups than others. Since policy is not a one-size fits all solution, we need a menu of policies that not only ensures adoption of sustainable practices, but also consumer access, and more importantly, that the consumer access is equitable and inclusive.

Our study has several limitations that provide opportunities for future research. First, we assess consumer accessibility to solar using utility website information as of spring 2020. There is fluidity in website information, making this study a snapshot of that time rather than intertemporal. We have lagged independent variables, capturing them archivally as of 2018. Second, our study draws on website information rather than policymaker and stakeholder accounts. Future research could draw more on policymaker and stakeholder attitudes toward equity in consumer solar electricity accessibility. Attitudes such as CSP intent, partnership support, and motivation for CSP may influence whether LMI accessibility is a key part of a utility's CSP offering. We capture several of these aspects through website reviews, yet future research could draw on policymaker or stakeholder roundtables for such information.

Third, we focus on macro-level policies in the form of solar incentives, renewable portfolio standards, and competitive market policies. Our approach focuses more on top-down policies, and less on bottom-up policies where communities come together to enact solar access through communicated aggregated choice or social movements (Sierra Club). Overall, our study provides insights in the interplay of policy and customer purchasing power with consumer accessibility to solar electricity. Our focus is on consumers' accessibility to sustainability offerings adopted by firms, rather than the widely studied firm adoption of sustainability practices.

CRediT authorship contribution statement

Ekundayo Shittu: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Validation, Funding acquisition, Writing – original draft, Writing – review & editing. **Carmen Weigelt:** Conceptualization, Methodology, Software, Data curation, Writing – original draft, Validation, Funding acquisition, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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