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Examining community solar programs to understand accessibility and investment: Evidence from the U.S.

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ABSTRACT

This paper examines barriers and drivers to investment in community solar programs in the U.S. The paper addresses two key questions: (i) What barriers and drivers influence community solar adoption, including in low- and middle-income households? (ii) How can the market potential for community solar be further unlocked beyond the group of early adopter utilities and developers? The research team used a three-phased methodology consisting of stakeholder interviews, a survey, and a stakeholder engagement workshop. The main findings of the paper are: First, leading barriers to adoption are the absence of state and federal policies and standards, difficulties in subscribing customers, and lack of education, financial viability and suitable location sites; Second, the major drivers for adoption are enhancing community benefits and resiliency and grid modernization efforts. Improving financial viability is possible through, for example, the use of anchor tenants to mitigate financial risk and improve value-stack and sustainability efforts. To unlock the market potential for community solar programs requires addressing six categories of issues: (i) increasing community solar programs' generation limits and use of a portfolio approach to development and financing to achieve economies of scale through multiple projects, (ii) community education, project coordination and site selection, (iii) incorporating community solar programs in grid modernization and resiliency efforts, (iv) standardizing community solar programs policies, (v) mitigating interconnection financial burden, and (vi) designing dynamic contracts with anchor tenants that mitigate subscription issues.

1. Introduction

In the last decade, from 2010 to 2020, electricity generated from solar energy has grown at an average rate of 49% per year in the U.S. (SEIA, 2020a; Cohen et al., 2020; Bolinger et al., 2020). This phenomenal growth rate reflects the adoption of solar technology across all sectors, including utility-scale, industrial, commercial, and residential projects for both on and off-site generation. In the last five years, community solar projects (CSP) have comprised a noticeable portion of the new installations. A CSP allows multiple customers to share a single solar installation to harness the benefits of economies of scale to lower the costs of participating in solar for each customer. As of the third quarter of 2020, there were 2579 MW of CSPs spread across 40 states, and at least 19 states had programs designed to encourage or permit CSP installations (Gahl, 2020; SEIA, 2020b). The objective of this paper is to understand the factors that influence the adoption of CSPs and highlight how the CSP market potential could be further unlocked to increase adoption rates, including CSP adoption in low- and middle-income (LMI) households. In conducting a thorough examination of the factors influencing CSP adoption, this paper aims to isolate barriers and

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identify mitigation efforts to understand how policy recommendations could be enhanced for CSP adoption.

The growing interest in community solar projects can be attributed to many of the same factors that have stimulated other distributed energy projects. Such factors include declining installation costs, state and federal incentives, including the Investment Tax Credit, and consumer interest in the long-term cost savings that can be derived from low-cost solar driven by technological learning (Barna et al., 2020; Shittu et al., 2019; Shittu, 2013). In addition, the increasing interest in reducing greenhouse gases and other pollutants emitted by fossil-fueled electricity generation has also contributed to the growth of CSPs. An added benefit of CSPs is that the subscriber's "ownership" of a portion of the project, the subscription, can be easily transferred since it is not associated with the subscriber's property or place of consumption. Many of these attributes make CSP participation particularly well-suited for consumers who may not own suitable property for an on-site project or wish to make only a small investment in solar. Given the benefits and versatility of CSPs, the question that arises is why are they not more widely adopted by consumers who might want an alternative to their electricity supply?

Another factor that may influence the adoption of community solar projects is the structure. The structure of a CSP makes it feasible for a governmental body, religious organization, or other charitable groups to develop and subsidize a project and share the benefits with LMI subscribers. Forty-four percent of all U.S. households are considered low-income, a designation based on an income range of 60–80% below the area median income. These households spend an average of 8.6% of their income on energy, a rate three times higher than non-LMI households (DOE, 2020). Serving LMI subscribers with CSPs would be a valuable step toward alleviating energy poverty and increasing energy equity. LMI households tend to be renters and live in older apartments. As non-property owners, LMI households have less influence over electricity decision-making and are less likely to have ownership of or access to a rooftop or ground-mounted space to install solar energy systems. These households also lack the upfront capital or credit scores to install solar systems themselves. These circumstances might explain why even though LMI households make up 44% of U.S. households (DOE, 2020), they represent only 15% of solar adopters (Barbose et al., 2018). Access to CSP could provide a stable and low-cost energy source, that would diminish their cost of electricity if the barriers to participation by LMI households could be overcome. Designated policy interventions are necessary to address the LMI barriers to CSP participation (O'Shaughnessy et al., 2020; Baker et al., 2021).

This paper employs grounded theory for qualitative data analysis to address these barriers experienced by LMI households and shed light on CSP adoption factors. The data collection process consisted of three phases: interviews, an online survey, and a workshop. The integrated methodology of three research tools is a unique approach in the community energy field. The process was initiated by interviewing 23 managers, developers and industry leaders to gain insight into their experiences relating to the barriers and opportunities for CSP adoption. The interviews were conducted at the Solar and Storage, Finance and Investment conference in Austin, Texas, between April 9th and 10th, 2019. The second phase of an online survey captured 171 participants from utilities, independent power providers, and policymakers and delved into the barriers and opportunities of CSP adoptions, emphasizing LMI inclusion. The survey distinguished between early adopters of CSPs and those yet-to-adopt. The last phase was a day-long workshop consisting of thematic panel discussions at a top U.S. research university with select industry stakeholders, policymakers, developers, and players from the utility sector.

This three-phase methodology underlines the main contributions on two fronts: First, the synthesis of the research design that integrates novel approaches on interviews, surveys and a workshop. To the best of our knowledge, we are not aware of papers in the literature that have examined CSP adoption using the nexus of the three research design processes used in this study. More importantly, this paper fills the gap in our understanding of the CSP domain by bifurcating the stakeholders into two groups – yet-to-adopt and early adopter categories. This division allowed for a meticulous analysis of the barriers and drivers with a cross-linking of the factors. Second, the outcomes of the deep examination reveal that the main barriers to CSP adoption include financing, regulation, insufficient industry and community education, and a lack of suitable locations for project sites.

Though financial challenges have broadly been listed as impediments to adoption of CSP, this paper distills the hurdles due to minimal cost recovery, profitability and risk mitigation. Regulatory barriers include limits on generation capacity and a lack of consistent standards and enabling regulations – these are more pronounced under efforts aimed at capacity expansions (DeLuque and Shittu, 2019). Industry and community education refer to the general knowledge gap about benefits and processes to pursue CSPs. Lastly, determining the location of the CSP, and the steps of evaluation and permitting, can delay project completion. The outcomes indicate six approaches for success to mitigate CSP challenges: increasing generation limit and portfolio approach for economies of scale, community education and project coordination, grid modernization and efficiency, standardization, interconnection, and dynamic contracts. These six approaches are developed throughout the paper, but an important term to introduce is dynamic contracts. Such contracts allow for flexibility in subscriber commitment lengths, such as 3–5 years instead of 20–25 years, and in the creditworthiness of subscribers. A key component of dynamic contracts is anchor tenants that serve as low-risk subscribers that provide financial stability for most of the project length while mitigating the participation of high-risk subscribers such as LMI. Both dynamic contracts and anchor tenants were deduced from the research analysis and explained at greater length under the workshop section 4.1.3 on how they enable CSP and LMI participation.

The information presented in the rest of this paper is organized as follows: Section 2 provides a focused review highlighting the background of community energy. In Section 3, the methodology and analysis framework of the phases are presented. Section 4 offers an evaluation of the data collected during the interview, survey and workshop phases. This section focuses on the challenges confronting CSP adoption, elements to increase inclusion through stakeholder engagements, strategic CSP adoption policies, and financial mechanisms. In order to distill the synergistic responses to the research questions, Section 5 offers a cross-sectional synthesis that integrates the phases of the research on the identified factors of CSP adoption and highlights how the market potential for CSPs could be unlocked. Section 6 is dedicated to the identified challenges and opportunities that could further spur engagement with LMI communities. Sections 7 aggregates and summarizes the recommendations. Section 8 concludes the paper with policy implications.

2. Background

The restructuring of the energy market in the early 1990s introduced new energy policies that influence firm-level competition and utility investments in renewable energy (Weigelt and Shittu, 2016; Shittu et al., 2015). These changes have increased the financial options and the legal environments governing the changes to the grid, as seen in the example of impacts of renewable-infused microgrid adoptions (Vine et al., 2017). The restructuring resulted in a rise of non-utility players in the electricity market. Some states expanded the federal mandate to unbundle wholesale supply from transmission to the retail level, which enabled the market structure known as retail electricity competition (O'Shaughnessy et al., 2019; Hess, 2019). This shift enabled individual energy choices and led the way to community-scale renewable energy projects.

Community energy projects can take several forms, the most prevalent being CSP. CSPs enable a business model where households, businesses, and non-profits can tailor renewable energy projects to their

needs (Coughlin et al., 2011; Funkhouser et al., 2015; Becker et al., 2017). CSP provides consumers an option for reducing energy bills or addressing climate change without waiting for the utility company to increase its renewable portfolio. However, some utilities offer their own CSP as a service option for their interested customers. In addition, community energy projects help decarbonize the grid by increasing the proportion of renewable energy due to their declining costs (Peters et al., 2018; Smith, 2019; O'Shaughnessy et al., 2019).

Community energy adoption faces multiple challenges. Capacity limitations, subscriber locations and eligibility, LMI participation and customer acquisition have all been identified as challenges for CSP adoption for utilities, developers and regulators (Cook and Shah, 2018). Energy poverty and insecurity perspectives (Urpelainen, 2016), multiple governance levels (Li and Yi, 2014), policy inconsistency (Simpson and Clifton, 2015), and concerns that net-metering benefits are not equally distributed throughout the economy (Simpson and Clifton, 2015; Jones and James, 2017) also influence adoptions. An increased awareness and CSP adoptions have fueled the debate around the fading importance of centralized grid systems (Asmus, 2008), which has influenced several economic and financial models to make both utility and non-utility providers more viable (Funkhouser et al., 2015; Coughlin et al., 2011; Chan et al., 2017). One such push is towards achieving economies of scale for small and medium-sized projects to increase adoption rates over single-home distributed solar energy systems (Noll et al., 2014; Chang et al., 2017). New economic and financial models depend on policy acts and influence newcomer participation in the market by providing adequate enhancing alternatives (Lam and Law, 2018).

Though the use of community energy continues to grow in popularity among investors and customers, it has faced various legal issues and opposition from utilities and public utility commissioners (PUCs) (Booth, 2013; Funkhouser et al., 2015; Smith, 2019). The threat that community energy poses to the traditional centralized energy industry depends on the ownership model and presence (or lack) of a competitive retail market. Two threats include loss of revenue and reliability impact on the grid with the increased introduction of distributed renewable sources. While electricity combinations with high-cost intermittent technologies have been shown to exhibit low market risks, they also tend to have less than optimal reliability measures (Deluque et al., 2018). As utilities are already positioned under political and operational pressure to maintain an adequate and secure grid, losing revenue undermines the utilities' ability to recuperate their investments (Hess, 2019). However, customers opting to non-utility-led CSPs do not cease paying the utility. These customers still pay a distribution fee, but the utility receives less money than before if it was previously supplying electricity and delivering it, or if the utility rates are structured to recover the costs of the distribution system based on the volume of supply delivered. On operations, in vertically integrated utilities, where generation is self-owned and not contracted out, if many customers leave the utility service, the utility is left with underused supply, another potential loss of investment (if costs cannot be recovered through wholesale sales). Lastly, resource adequacy planning could also be impacted by the inclusion and expansion of CSPs (O'Shaughnessy et al., 2019). These potential threats have influenced states and utilities to pursue changes in rate design and other lost-revenue measures to make sure utilities remain financially viable to provide transmission and distribution. It should be mentioned that CSPs are not the instigator of these challenges but form a part of the issues the traditional utility model experiences in the face of the shifts to onsite energy or third-party generation in general.

The promising news is that some utilities have started recognizing the benefits of community solar when self-led. For example, according to America's Electric Cooperatives, 227 cooperatives across 33 states have already invested in CSP offerings (America's Electric Cooperatives, 2020). Utility-led community solar mitigates several of the financial and operational concerns (Chan et al., 2017). Utilities can incorporate community energy in their primary operational strategy, but effectively doing so requires that utilities and communities participate in regional energy planning (Brandoni and Polonara, 2012; Becker and Kunze, 2014). By doing so, CSPs can be incorporated into localized grid modernization efforts, including smart grids and battery storage, to increase resiliency.

To achieve a strong collaboration requires recognizing that communities are essential in long-term energy management, social equity and decarbonization. Recent years have seen successful state and PUC-led CSP programs. Examples include a Maryland program intended to stimulate up to 200 MW of CSPs, targeting customer diversity and transition to retail-rate net metering (Wood, 2017), as well as a solar garden initiative in New Jersey (Chan et al., 2017).

Low- and middle-income programs have benefited from designated energy policies, but not all states designate CSPs as eligible uses under the benefit programs. Such LMI programs include the Low-Income Home Energy Assistance Program (LIHEAP) and the Weatherization Assistance Program (WAP). LIHEAP support LMI by covering heating and cooling bill payments and energy crises assistance (U.S. DHHS, 2014). On the physical improvement side, WAP supports eligible LMI households, senior citizens and disabled residents by reducing their utility bills through home efficiency improvements of new insulation and air sealing (Fowlie et al., 2018).

States that have tapped into existing LMI benefits for CSP adoption include Minnesota (MN), Colorado (CO), New York (NY) and Washington, D.C. (DC). Minnesota has tapped into these benefits by using LIHEAP funds by connecting their CSP to efficiency and renewable sources efforts (MN Department of Minnesota Department of Commerce, 2018; Clear Energy Resource Teams, 2020). CO, NY, and DC have followed suit by setting aside designated resources for CSP in LMI communities (Low-income Solar Policy Guide, 2020; DCDOEE, 2020). These examples illustrate that the industry has the motivation to invest in CSP. Now, the question remains on how best to do so on a wide scale.

3. Methods

The three stages of research presented in this paper are based on stakeholder engagements through a set of qualitative and quantitative approaches (Pizarro-Irizar et al., 2020; Sarkisian, 2020). The analysis approach utilized is grounded theory for qualitative data (Glaser and Strauss, 2017; Corbin and Strauss, 2014), a tool for generating new theory grounded in the field and set in the context of an existing theory. While the grounded theory does not test an existing hypothesis (Kennedy and Lingard, 2006), it focuses on generating a general framework from the research perspective. This inductive-deductive interplay suggests substantial value to expose the motivations, barriers and solutions to CSP adoption.

The data from the interviews, survey and a workshop lead to tentative theories on CSP adoption and have been successful in energy stakeholder analysis before. Anne and Achyut (2018) based their research on a workshop that included power providers, low-income and clean energy advocacy groups, government, researchers and developers, financial institutions and legal counsel. Michaud (2020) utilized semi-structured phone interviews to examine community shared solar policy in the U.S., relying on grounded theory for thematic analysis (Michaud, 2020). Evidence supporting the use of a workshop was found following a similar workshop effort to understand LMI involvement in community solar in the Southeast U.S. (Anne and Achyut, 2018). Our methodological contribution is applying the iterative and integrative grounded theory concept (Boychuk Duchscher and Morgan, 2004). The value is in the comparative analysis across phases to find synergies and differences and extracts explanations of the investigated social phenomenon (Corbin and Strauss, 2014).

The flow and focus of each stage are represented in Fig. 1 below. The orange represents the within-phase analysis, acting as the summary flow of findings to the phase goal. Example findings are provided for each within-phase analysis in the orange boxes. The bold black line arrows represent the.

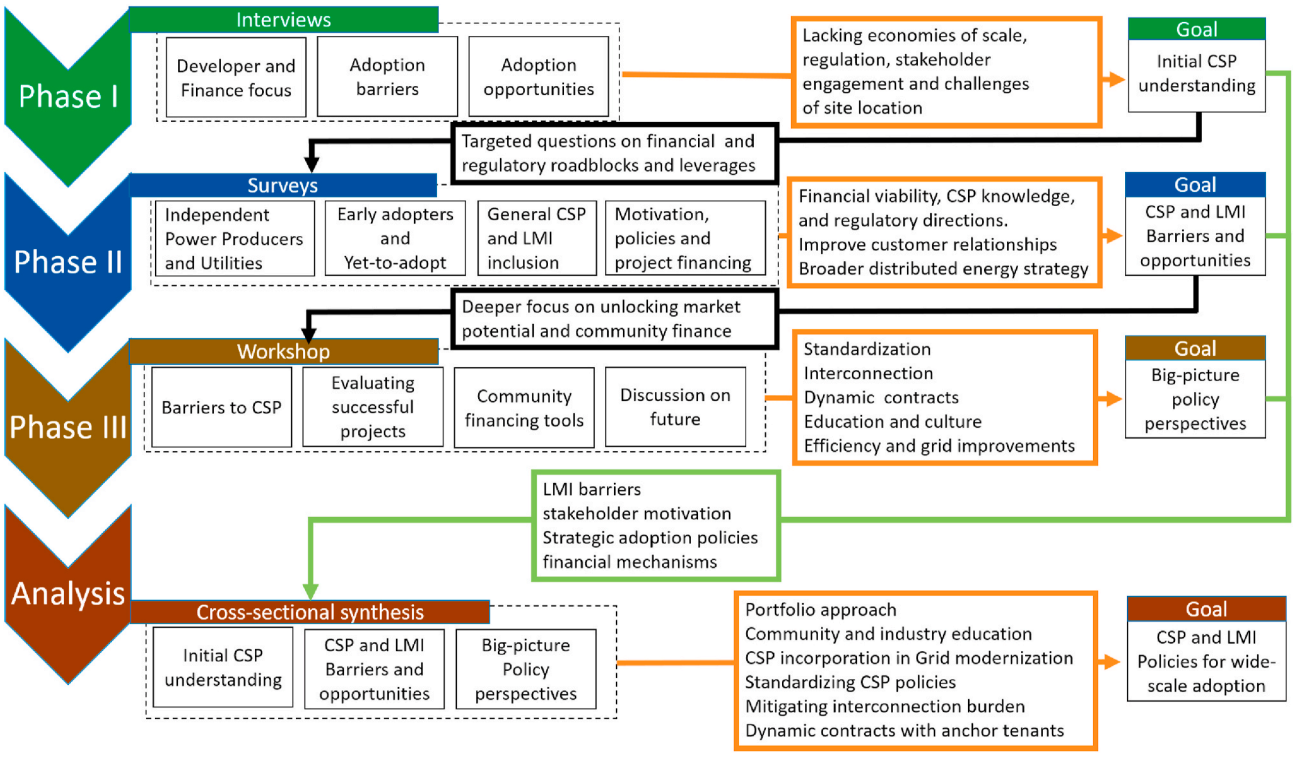

Fig. 1. Research design.

output/input flow of information between phases, *i.e.*, how the preceding phase influenced the proceeding one. As can be seen in the input-output flow between the interviews and the survey phases, the main influence was formulating targeted questions on financial and regulatory roadblocks and leverages in the survey questionnaire to offer focused insight past the initial CSP understandings. Between the survey and the workshop, the emphasis was to push past organization-level perspectives and develop a deeper dive into market-wide perspectives. Lastly, the green information flow represents the synthesis across phases, aiming to capture LMI barriers, stakeholder motivations, strategic adoption policies and financial mechanisms as the cornerstone of the analysis.

In the first research phase, 23 interviews were conducted at the Solar and Storage, Finance and Investment conference in Austin, Texas on April 9th and 10th, 2019. The conference was chosen both for the audience and content. The participating organizations represented a broad range of the energy sector: power providers, developers, financiers, policymakers and advocacy groups. Alongside the benefit of capturing the broad range of organizational perspectives, the added value was the participation of members who held upper-level management positions. The positions of the interviewed participants include chief executives, marketing and technology officers, vice presidents, and regional managers. The content of the conference included the challenges, opportunities and financial dimensions of solar energy and storage, two leading drivers of today's energy industry and decarbonization enablers.

Interviews can provide a deeper understanding of the complexities in the residential solar market (Sinitskaya et al., 2020; Gao and Yuan, 2020). The initial set of interviewees in the research presented in this paper was determined based on the published list of participants on the conference webpage. The interview group included executives from utilities and coops, small-to-large scale developers and installers, advocacy groups and financial consultants, emphasizing developers. Invitations were sent ahead of time using the conference meeting schedule tool to share the research goal and request an interview. At the conference, additional interviewees were identified by observing the panel presentations and breakout sessions. All interviews, lasting 15–25 min, were conducted prior to, between and after conference sessions. The goal of the interview phase was to capture firsthand CSP experiences as seen through the perspectives of upper management across industry representatives. The value is capturing real-world "on the ground" insight into the barriers and opportunities facing CSPs and LMI participation. The interview questions presented in Table 1, focused on the organizational role, capabilities, barriers and future CSP directions. The key column will tie back analysis outcomes to each question.

The goal of the second research phase was to reach a broader range of stakeholders in the utility and community solar ecosystem. The online survey enabled a deeper dive into CSP and LMI perspectives, distinguished by organizations that adopted CSP, known as early adopters, and organizations that are yet-to-adopt. The distinction allowed a comparative analysis with the goal of illuminating the adoption and barrier experiences of the early adopters to mitigate the barriers of the yet-to-adopt organizations. Surveys are effective in extracting information from engaged stakeholders, especially for renewable energy deductive analysis (Lacerda and van den Jeroenvan den Bergh, 2020; Setyawati, 2020; Chen et al., 2020).

With Institutional Review Board (IRB) approval, the survey was

Table 1
Conference interview themes.

Interview questions	Expanded dialogue	Key
Do you participate in CSP initiatives? Why or why not?	If yes, what is your organization's role? What were your challenges and motivations?	I.1
What non-utility partners do you work with (or need to work with) to make CSP a reality?	Who initiates stakeholder networks interactions?	I.2
How would you include LMI participants in CSPs?	What challenges and motivations do you have?	I.3
What does the future of CSP look like?	What needs to change for you to achieve this?	I.4

completed between July 9, 2019 and August 27, 2019 with 174 responses. The platform used was Qualtrics, providing ease in structuring the survey and data collection. The pool of responders was informed by the relevant stakeholder groups, emphasizing power providers, utility players, financial service providers, regulators, and policymakers. Responders included managers, directors, and executive-level officers across the industry. The designation of responders as early adopters or yet-to-adopt was achieved by an early survey question of whether the responder has at least one CSP in their portfolio. The responder was directed to the set of questions depending on the answer, seen in Tables 2 and 3.

The third research phase was a one-day workshop convened at a top research University on February 7, 2020, with stakeholders including government officials, representatives of Non-Governmental Organizations (NGO), energy investors, community advocates, utility representatives, and energy law experts. The goal was to elicit experiential information from industry leaders and stakeholders through dialogue. The participants were invited based on the established solar professional network known to the research team and several interviewees from phase 1 as part of follow-up engagement. The workshop was conducted as a series of themed panel discussions, with active participation from the audience. The four panels covered barriers to community solar, evaluating successful implementation, financial prospects, and a general discussion on pertinent matters for the future of CSPs. The workshop panels and respective goals and questions can be seen in Fig. 2 below. The workshop analysis was based on extracting qualitative themes and synergies from the workshop transcripts, translated into recommendations. Workshops have often been deployed to unearth barriers to technology adoption in a manner that allows dialogues by engaged stakeholders (Queiroz et al., 2020; Angelopoulos et al., 2017).

The guiding principles for the questions in the three research phases are explained in Table 4. To avoid repetitions of questions, we provide a column for the summary themes, accompanied by their respective theoretical and practical bases. The theoretical and practical basis echo the within-phase and between-phase information flows.

3.1. Approaches to data analysis

In the interview phase, the interviews were semi-structured, based on open-ended questions and follow-up based on the conversation flow. The responses were grouped under different categories using a codex developed by the research team. The survey analysis relied on comparing the two populations, the early adopters and yet-to-adopt. The second comparison revolved around whether LMI participants are, or will be, included in CSPs. These two pivot points offered the broadest levels of comparisons.

Table 2
Early adopters Survey Question Themes.

Early Adopters	Format	Key
What type of 3rd party partnership does your organization have?	Yes/no for 5 CSP aspects	SA.1
How would you evaluate your organization's CSP motivation on customer relations, grid performance, sustainability and policy compliance?	7-tiered Likert Scale on 7 parameters	SA.2
Which policies either at state or federal level affected your organization's motivation for adopting CSPs?	Open responses	SA.3
Does your organization have CSP installations in LMI communities? Why or why not?	Yes/no, open response	SA.4
Is CSP project financing method influenced by the intent to involve LMI participants? What major decisions are different for LMI?	Yes/no, open response	SA.5
Ease of consideration to include LMI?	Easy Decision/Debated/ Controversial	SA.6
What are your key initiators for including LMI?	7-tiered Likert Scale on 3 parameters	SA.7
What were strong barriers to including LMI?	7-tiered Likert Scale on 6 parameters	SA.8

Table 3
Yet-to-adopt survey question themes.

Yet-to-adopt	Format	Key
What are major barriers for your organization to adopt (owning, developing, implementing) a CSP?	7-tiered Likert Scale on 18 parameters	SY.1
Which financial method will help you adopt a CSP?	open response	SY.2
To what extent do you consider customer subscription, financials, policy and partnerships a major barrier to including LMI participation in CSPs?	7-tiered Likert Scale on 9 parameters	SY.3
To what extent is your organization's plans to adopt CSP in the future motivated by customer relations, grid performance, sustainability and policy compliance?	7-tiered Likert Scale on 7 parameters	SY.4
If adopting a CSP, will it include LMI households? Why or why not?	Yes/no, open response	SY.5
Will your financing decision be influence by LMI participants? If yes, what would be different?	Yes/no, open response	SY.6
Is your decision to include LMI participants in the future driven by state and federal policies? If yes, which ones?	Yes/no, open response	SY.7
Do you see community outreach NGO as a factor in whether your organization will attempt to provide access to LMI households on future CSP projects?	Multiple choice	SY.8
What do you see as the most important benefit for your organization from LMI participation in CSPs?	Multiple choice	SY.9

A key dimension of the survey focused on barrier rating and policy identification. Early adopters and yet-to-adopt were asked to rate the significance of different potential barriers to their adoption of CSPs on a 1–7 range Likert scale with qualitative terms from "none" to "major." The Likert scale responses were counted to obtain the percent contribution of each perception of the barrier's influence. By characterizing the "none" and "barely" as non-challenging, barriers can be ordered by the most challenging to least, where most challenging corresponds to a barrier with the highest overall challenge percentage. Open-ended responses were analyzed with the same codex as phase one for consistency.

The workshop analysis was based on extracting qualitative information from the workshop transcripts. The qualitative analysis incorporated the distinction of states with or without enacted CSP policies and LMI participation. The information was then translated into synthesized themes, one set for general CSP and another for LMI inclusion through highlighting shared solutions. The leading approach to synthesizing the data was to compare the results of each phase, identifying synergies and conflicts.

3.2. Composition of the stakeholders

The target demographics across the phases aimed to balance representation of the stakeholders. Developers were emphasized in phase 1, power providers in phase 2, and policymakers, both NGOs and government participants and academics in phase 3, as presented in Table 5.

Observing the demographic distribution may, however, suggest the stakeholder composition does not offer a balanced representation, specifically of government, academics and consulting. However, there are several mitigating factors in the research design. First, having multiple phases with different focus points allows for broad perspectives. Second, though government and academics are not as represented in the interview phase, it was important to capture the industry participants as the preliminary practical and theoretical basis of the research. Third, the workshop, and to a large extent the survey, allowed the government and academic stakeholders to ratify and provide a comprehensive evaluation

Fig. 2. Snapshot of the Workshop structure and dialogue.

Table 4
Phase thematic questions and respective theoretical and practical basis.

Phase	Thematic questions	Theoretical basis	Practical basis
Interview	Why/Why not do you participate in CSPs? What non-utility partners do you/need to work with to make CSP a reality? What is the future of CSP and how would you include LMI participants?	Rationale for firms' engagement in CSPs Identification of key partners Understanding future CSP dynamics	Isolate CSP considerations Need to determine beneficial partnerships Map financial and regulatory pathways
Survey	Which state or federal policies influence adoption? Which financing methods influence adoption What are leading barriers and motivations? How does LMI influence decisions?	Identify beneficial policies Understand barriers to financial viability Isolate motivations and energy strategies Explore LMI influence	Organization level policies Highlight opportunities to unlock market potential Explore community finance
Workshop	How can utilities overcome barriers? What cross-collaboration is essential? What is the role of policy intervention in community and LMI financing? What is the future of CSP?	Develop business approach Industry collaboration Capture standardization priorities Mitigate finance and subscription issues	Business strategy Isolate education and outreach efforts Align state and federal practices Big-picture policy

Table 5
Composition of the engaged stakeholders.

Stakeholder	Interviews		Survey		Workshop	
Power providers	5	22%	120	69%	1	3%
Government	0	0%	27	15%	6	15%
NGOs	2	9%	7	4%	9	23%
Developers/installers	11	47%	12	7%	7	18%
Financial institution	2	9%	7	4%	3	8%
Consulting	2	9%	0	0%	5	13%
Academic	0	0%	0	0%	8	20%
Others	1	4%	1	1%	0	0%
Total	23		174		39	

of the observed interactions/themes/findings from the previous phases. Lastly, and technically, to avoid confirmation bias, the team allowed the process, especially on the survey, to be independent of the choices of respondents. These factors provide confidence for the research team in the breadth and depth of the analysis.

Another characteristic to highlight is the CSP experience of the research participants. Of the 23 interviewees, six were from organizations with CSPs, with 87% of the rest interested in adopting CSPs in the upcoming years. The five power providers in phase 1 include investor-owned utilities (IOUs) with coops and a distribution authority grouped with them. In the survey phase, the early adopters represent 122 of the 174 responders. The 120 power providers are comprised of 49 IOUs (41%), 36 independent power producers, IPPs (30%), 25 municipal-owned utilities, MOUs (21%), and 10 Coops (8%). Over the next five years, about 47% of the survey responders believe that their organizations will be investing/adopting CSPs, 25% were certain that their organizations would not venture into CSPs, and another 28% were not sure. Of those saying yes, thirteen are pursuing it in the next year, six in the following 1–2 years, one within the next five years, and seven were

unsure of when. The workshop had a similar mix of developers with or without CSP/LMI experience, but most of the other participants were involved with CSPs daily.

In the next five years, the organizations with plans to adopt CSP were almost equally split on whether to include LMI, with twenty-eight saying Yes, and twenty-nine saying No. This distribution is correlated with the proportion of LMIs in their service territories. A utility with LMI representing 10%–15% of customers served does not experience the same urgency to design programs and business practices as a utility with over 50% LMI representation. Fig. 3 provides the LMI characteristic of phase 2 respondents.

On the left is the LMI customer proportion of the yet-to-adopt organizations, demonstrating the significant opportunity in aiding these organizations to adopt CSPs. On the right, one can see that 95% of early adopter organizations (108 organizations) already include LMI participants in their CSPs.

4. Data curation and discussion

In this section, the outcomes of the activities are presented according to the challenges of adopting community solar projects in general, increasing community inclusiveness through stakeholder engagement, and understanding strategic and financial policies to enhance adoption decisions.

4.1. Challenges confronting CSP adoption

The frame of observation discusses the challenges that were identified through interviews, survey and the workshop. In this section, the barriers of CSP are expressed and are compared across the phases, with an additional focus on LMI perspectives.

4.1.1. Interviews

The adoption barriers identified by the interview phase are seen in Fig. 4.

The top three most frequent barriers are economies of scale, regulation, and stakeholder engagement. Responses were similar across those with and without a CSP, with the same top barriers but different order for the 2nd, 3rd and 4th barriers. Lack of economies of scale refers to the fact that CSP generation capacity is often much smaller in MW capacity than utility and industrial scales, therefore not as profitable given the relative time and soft costs needed for any project size (O'Shaughnessy et al., 2019; Peters et al., 2018). For most developers and power providers at the conference, small-scale community projects are outside the scope of their organization because they prefer to spend time on utility, industrial and commercial-scale projects. The Coops and MOUs, however, did report CSPs as integral to their agenda.

Regulation refers to the lack of political support from local and state governments and utilities to incentivize CSPs by making them more profitable or share the burden of financial risk. The adoption of PV systems is partly a function of local-level regulations (Graziano et al., 2019; Koirala and Hakvoort, 2017). Stakeholder engagement refers to the general motivation of the community or business to participate in CSPs. Organizations have a difficult time finding interested partners and challenges in project collaboration with related parties. Lastly, the fact that location is ranked 4th should not be overlooked as a lesser obstacle, and developers, providers and advocacy groups have indicated the long project delays caused by zoning and acquisition processes (Schunder et al., 2020; Mensour et al., 2019).

4.1.2. Survey

The adoption barriers from the survey add both new and reinforcing findings. The yet-to-adopt responses, presented in Fig. 5, report the top barriers as (1) low cost of existing energy contracts for traditional energy sources, (2) high cost of implementing CSP, (3) lack of CSP knowledge, (4) not seeing the return on investment (ROI), and (5) lack of community demand.

The high cost of CSPs and lack of ROI go hand in hand with financial adoption barriers. Unlike in the interview phase, lack of CSP knowledge in the pursuing organization is a top barrier, affecting over 80% of yet-to-adopt organizations. Lack of developer and utility CSP knowledge captures the notion that many in the energy industry are still unsure of the CSP best practices and how to successfully pursue community energy projects. The remaining medium barriers can be categorized as policy and incentive-focused. Again, lack of suitable location is highlighted as a medium barrier and recurring theme. At the other end of the spectrum are factors that have marginal effects on adoption hindrance. These include existing investments in other renewable energy sources and utility-scale projects, and investments in natural gas that do not seem to concern 40%–45% of respondents. This is a promising insight suggesting CSP does not have to compete with other energy priorities for organizations.

4.1.3. Workshop

In a disagreement with the yet-to-adopts' challenge given lower traditional energy contracts, the workshop phase reported the ever-falling prices of solar energy as opportunities to overcome CSPs financial obstacles. This discrepancy might be attributed to a perception gap between early adopters and those yet-to-adopt, which influences community energy business knowledge and models and demographic differences in the phases. In the workshop, the first panel took a deep dive into barriers of both utilities and non-utilities, summarized in Table 6. Though only reporting customer education and outreach as the main challenge, utilities report overcoming financial and motivational barriers by recognizing that CSPs offer financially viable solutions that support environmental issues and grid security compliments. Non-

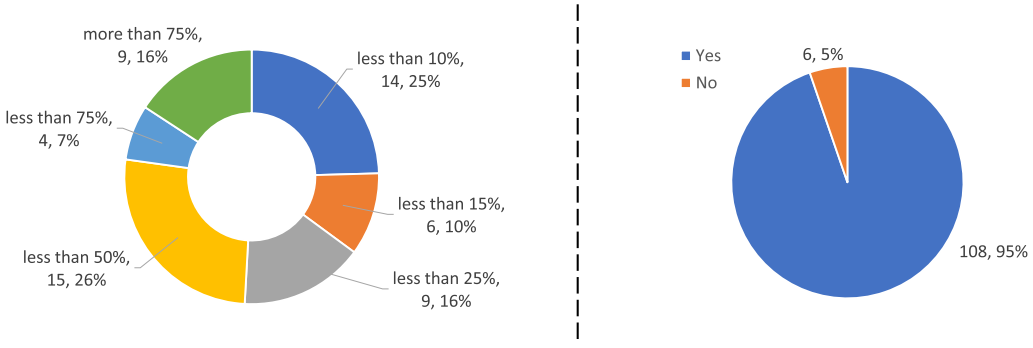

Fig. 3. LMI composition of survey respondents. Left: yet-to-adopt breakdown of the percentage of LMI customers they serve. Right: early adopters that have CSP in LMI communities.

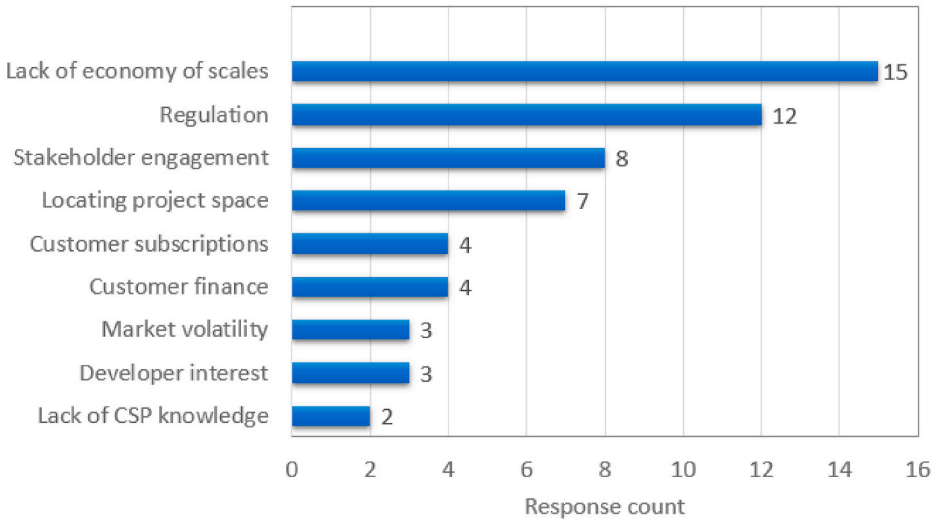

Fig. 4. Barriers to CSP adoption based on the responses by solar conference attendees.

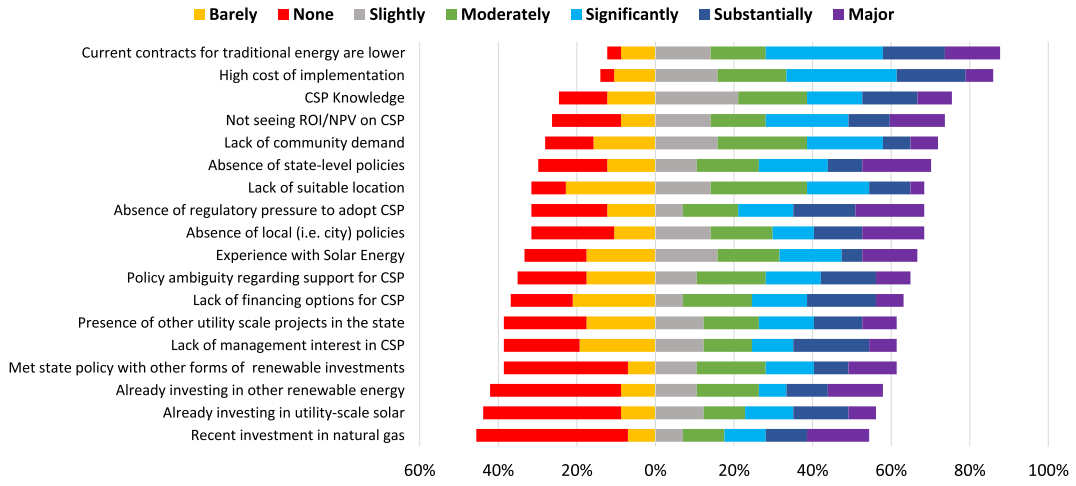

Fig. 5. Barriers to adoption as provided by organizations/utilities that are yet to adopt CSP.

utilities, however, communicate four main barriers: (1) lack of standardization of practices and legal status, (2) customer acquisition and related business model, (3) accessing project locations, and (4) competing with utility and commercial scale.

In addition to the key findings presented in Table 6, the last column captures the related color-coded themes that were deduced and synthesized from the workshop phase: standardization, interconnection, education and culture, dynamic contracts, and grid modernization and efficiency. Standardization relates to regulation and practices, both policy and industry, that require purposeful policymaking to streamline and standardize CSP. Interconnection relates explicitly to overcoming the financial burden of CSP grid connections, a heavy barrier for small-scale developers and customers.

Education and outreach focus on equipping all stakeholders with CSP best practices. Dynamic contracts, as introduced earlier, captures the need to offer flexible contract lengths and credit score mitigation such as anchor tenants. Again, anchor tenants serve as high-credit low-risk "anchors" that provide longevity for a CSP while enabling LMI households to participate by mitigating financial risk concerns. Lastly, grid modernization and efficiency relate to broader energy strategy and resiliency. Each panel summary has been incorporated in the appropriate paper section. The five themes were prevalent across the four workshop panels, and several findings addressed multiple themes as they are interrelated.

The "Customer acquisition" barrier captures the lack of community education on the benefits of CSPs, the limitations of traditional lengthy contracts, and a business model that favors higher income customers. Subscription is also the main challenge for utilities, but education and subscription campaigns can help overcome the customer acquisition barrier. The coupled limitation is that traditional business models favor high-income earners with strong credit scores. As the financial security of projects is influenced by creditworthiness, large segments of potential customers are at a disadvantage. These barriers pave the way for the need to create dynamic contracts that account for varying contract length and financial risk of applicants to mitigate concerns of the long-term commitment of the subscriber on the one hand and investment security for the developer on the other.

Additional barriers include the standardization, which represent the challenge of operating in an industry where each state, municipality and power authority have their own policies or lack thereof. In a non-unified field, it is difficult for most stakeholders to navigate CSPs and align, or finance, the myriad procedures required. The outcome of lacking standardization is longer and costlier development and implementation processes. To remove the barrier, standardization should cover aligning

Table 6
Workshop Panel A on barriers: Summary of findings.

Question	Key Finding	Theme
How have utilities overcome traditional barriers to CSP?	Customer education and outreach.	
	Realities of cost, innovation, environmental issue and grid security.	
How are utilities and stakeholders impacted?	Conflict of interests in zoning and land prices.	
	Determining interconnection cost burden.	
	Increase of wholesale markets.	
What challenges have non-utilities met with CSP initiatives?	Absence of standard practices or legal status.	
	Subscription, contracts, and business model.	
	Use of roofs, parking, brown fields, landfills.	
	Competing with utility and commercial scale.	

Standardization Interconnection Dynamic contracts Education and culture Efficiency and grid improvements

incentives, goals and benefit programs.

In addition to standardization, accessing land is a recurring barrier. The specific issue raised in accessing land is that ideally, one must access land that otherwise has no other conflicting purposes, such as rooftops, shaded parking lots, brown fields and landfills. However, acquisition or leasing these spaces is a long and laborious process, depending on the property owner.

The last non-utility barrier refers to developers and power providers' competing preferences for utility and commercial-scale projects. This finding aligns with the barriers shared in the early phases, where larger projects benefit from economies of scale. Impacting both utilities and non-utilities are two related matters. The first is the interrelated matter of zoning, which is a significant influence on possible locations and prices, and the second is land prices which include the cost of interconnection. The interconnection cost is often disproportionate to the cost of the small-scale CSP, and the burden to pay is on the developer and customers. The result is a jeopardized viability of smaller-scale projects. In addition, a dilemma tends to exist between expensive properties that are close to the customers, where interconnection is cheaper and cheaper properties in rural parts that are distant from customers, where interconnection is expensive.

Competition with utility-scale is another way of identifying the disadvantaged financial viability when economies of scale are absent. Concerning LMI, there are similar barriers to greater emphasis on education, outreach and subscription, and financial risk mitigation.

4.1.4. *Barriers to LMI installations*

The top five LMI barriers for the yet-to-adopt are available in Fig. 6 along all presented barriers.

The leading barriers related to the total cost of LMI household participation, the process of signing and educating LMI households, identifying suitable candidates, and the additional outreach effort needed. These align with the general CSP barriers but are felt to a greater degree when LMI households are included, increasing financial

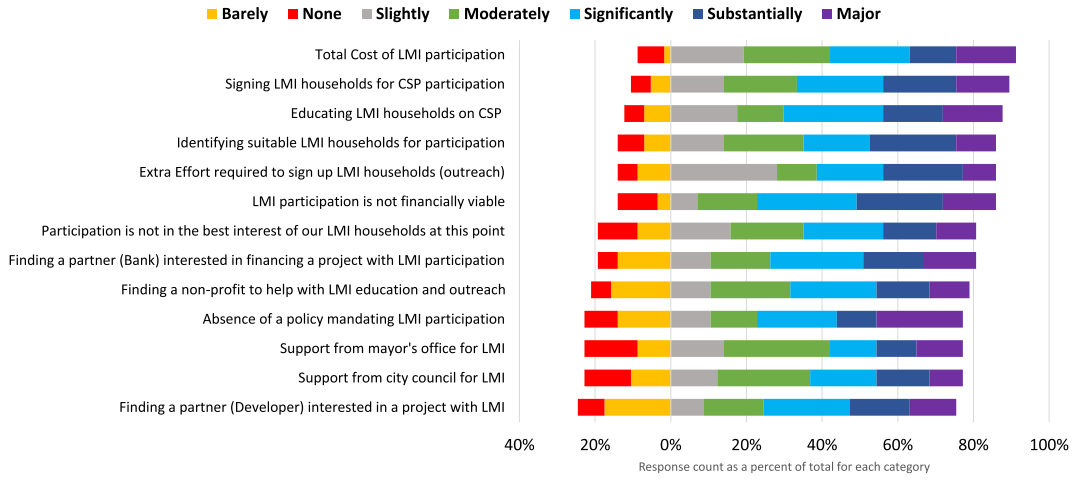

Fig. 6. Barriers to adoption in LMI communities by yet-to-adopt CSP entities.

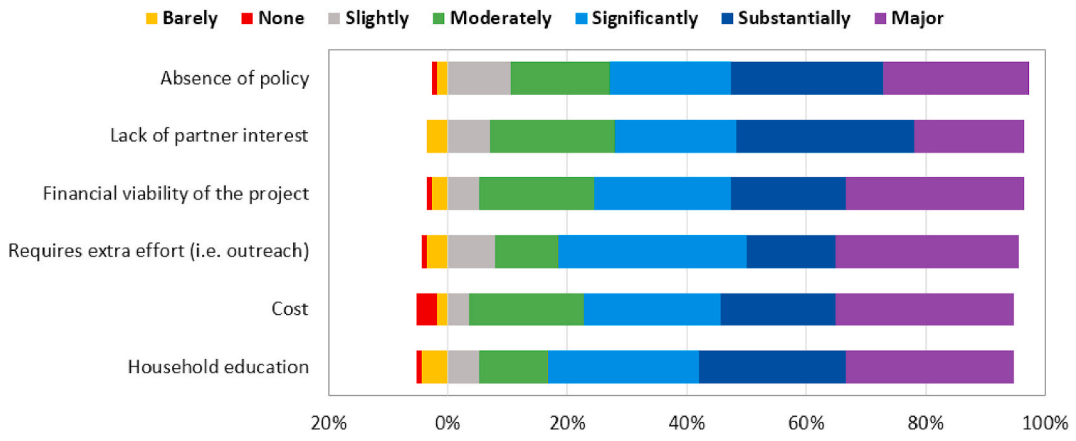

Fig. 7. Barriers to adoption in LMI communities by early adopters of CSPs.

uncertainty and educational outreach.The early adopters suggest a different perspective, seen in Fig. 7.

The absence of policy, lack of partner interest and financial viability are the top barriers. Compared to the yet-to-adopt community, it is noticeable that cost and household education are relatively the lowest, whereas, for the yet-to-adopt respondents, cost was the main barrier and household education the 3rd. A point of evaluation is that early adopters recognize all potential barriers as challenging with only a small minority, between 5 and 10% (Fig. 7), considering a barrier as barely or not challenging. However, in the yet-to-adopt community, all potential barriers have responses between 10 and 25% as barely and not challenging. The contrast might suggest a misperception of the extent barriers pose to LMI inclusion in CSP and the effort needed to overcome them, a point echoed with the general CSP barriers in section 4.1.2.

4.2. Increasing stakeholder motivation for CSP adoption

In this section, the general CSP and LMI adoption and motivation themes are provided. Emphasis is made on the difference between early adopters and yet-to-adopt organizations in efforts to identify knowledge gaps.

4.2.1. Motivating general CSP adoption

Recognizing the barriers for CSP and LMI is the first step to mitigating them. The second step is understanding the motivations organizations hold about whether to adopt and which partnerships were beneficial. Based on early adopters, the role of third-party partnerships is critical for successful CSP implementation. The majority of early adopters report established partnerships with third-parties for various issues, seen in Fig. 8.

The survey phase provided strong evidence that good partnerships

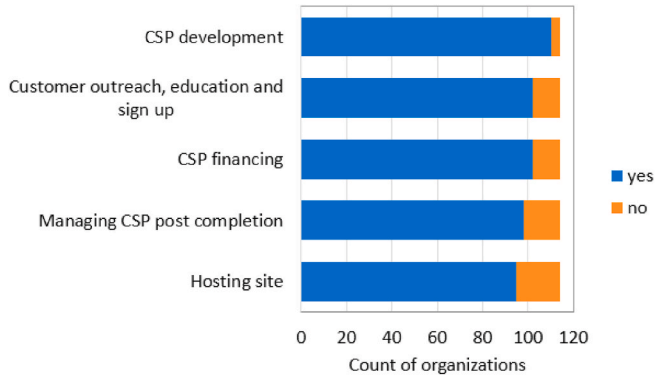

Fig. 8. Partnerships between early adopters and not-for-profit entities.

are the most important factor contributing to successful CSP development, followed by an effective customer outreach, education and sign-up program and the availability of financing options. It is also important to notice that almost all CSPs rely on a third party to manage the project post-completion. These topics, especially customer outreach and housing site, are recurring themes across our project research phases, including the interviews, survey and workshop. The recurring theme of hosting site is ranked last, but 83% of organizations report receiving support on securing a location. The implication of the strong reliance on partnerships aught signal the yet-to-adopt to pursue these networks and for these networks to reach out to the yet-to-adopt.

The motivations to pursue CSPs between the early adopters and yet-to-adopt are somewhat similar, seen in Fig. 9. For both early adopters and yet-to-adopt, improving customer relationships and broadening their distributed energy strategy are two of the top three motivators.

The two main differences are with ratepayer interests and policy opportunity. Early adopters signal ratepayer interest as a top priority but yet-to-adopt express it as the least important motivator. Conversely, policy opportunity is the top motivator for yet-to-adopt, but second lowest for early adopters. Policy opportunity refers to taking advantage of beneficial non-mandatory policies. A point of interest is that both groups identified sustainability goals and social good as a medium to low overall significance. The interview phase did not find sustainability or climate change a main driver; the workshop emphasized it to a greater extent.

The results suggest that most industry stakeholders conceptualize CSPs as meaningful components in customer-power provider interactions and distributed energy strategies, modernization and efficiency improvements. The interview and workshop phases added battery storage into CSP as a financial and technological incentive to improve the value stack of projects. A higher value-stack enables greater financial incentives to pursue CSP projects. In turn, it would encourage more developers and communities to adopt CSPs.

Although federal and state regulators have made significant strides toward incorporating storage into the regulatory structure, some inconsistencies still exist, leading to regulatory uncertainty or difficulties in assuring cost recovery. Regulatory uncertainty portends dire consequences on investment decisions (Shittu and Baker, 2009; Baker and Shittu, 2008; Kamdem and Shittu, 2017). Storage is versatile and can serve as both a generation resource and transmission or distribution system resource. However, the lines of authority over its deployment must be clear; for example, a commitment as a transmission resource that places it under the transmission operator's control could limit its utility as a generation resource. Cost-of-service recovery mechanisms for its value as a transmission resource have to be reconciled to cost recovery mechanism for its value as a generation resource, which is more likely to be market-based. If installed in conjunction with a renewable

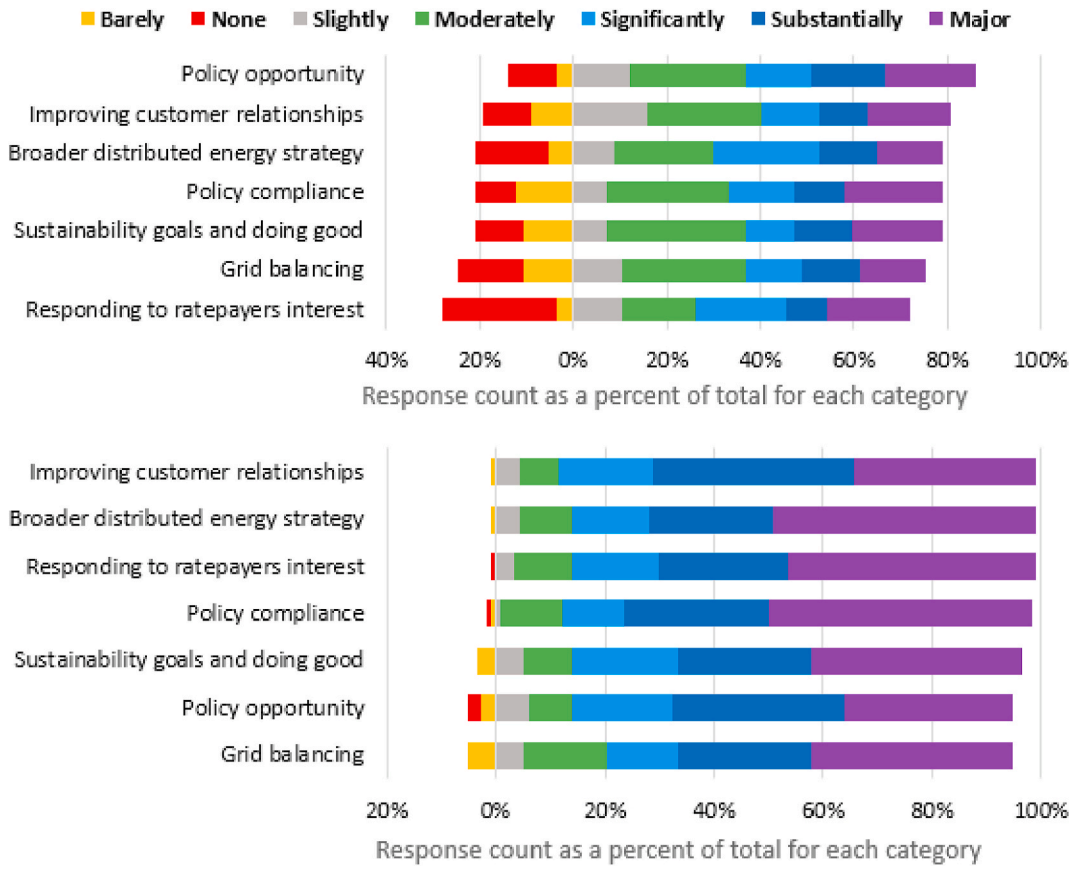

Fig. 9. Elements to motivate CSP adoption – Top: Yet-to-Adopt; Bottom: Early adopters.

resource but grid-connected as well, the renewable may be disqualified from net metering. As a result of the variations in federal and state law, the obstacles differ in severity in different parts of the country. Fortunately, the obstacles are being addressed bit by bit, and storage is being more easily integrated into the electric system in areas in which its costs can be recovered. Storage and solar further raise the potential for additional tax and financial incentives. The bottom line is that many developers see storage as the next key technology component of CSPs that can further the adoption throughout communities.

With the motivations in mind, which policies helped or would have helped, CSP adoption? The most prevalent policies to encourage CSPs are financial support and mandating standards and regulations, seen in Fig. 10. Financial support includes financing options, tax benefits, and insurance policies. Standards and regulations related to policy mandates for developers and utilities to offer CSPs and enable them to do so on a financially viable basis. The third category of influence was found to be motivation, *i.e.*, the state incentives to pursue CSPs.

The role of national energy strategies and environmental policies remains to be considered. In a similar way that renewable portfolio

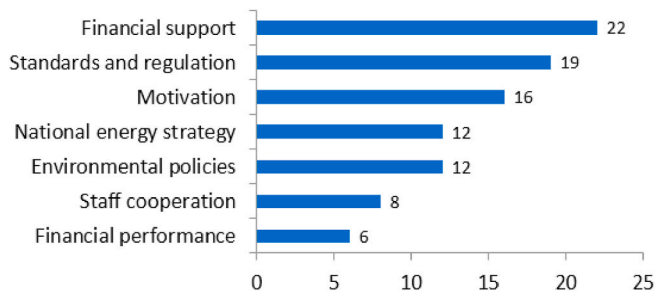

Fig. 10. Early Adopters' indications of important policies.

standards promoted the rise of renewable energy, national energy strategies that prioritize CSP national goals, perhaps as part of the solution for energy equity and cost-effective means to promote solar deployment, would further push the industry towards CSP adoption. Likewise, environmental policies that focus on decarbonizing the grid could also focus on CSP as a complementary mechanism alongside other solar projects. Energy strategy and environmental policy have in common the required prioritization of CSPs on a policy level, such that policy variance has strategic differences on adoption proportions (Ogunrinde et al., 2018).

4.2.2. *Motivation for the inclusion of LMI communities*

There are diverse motivations across both early adopters and yet-to-adopt, with the majority in both indicating community benefits as the main motivation. Both groups reported similar motivational themes, though in different terms and rankings aside from the top one of benefiting communities ("community benefits" for early adopters and "do well by doing good" for yet-to-adopt). The difference in terminology result from analyzing the open-responses of the early adopters, whereas the yet-to-adopt responded based on presented options. As shown in Fig. 11, the second-highest motivation for the yet-to-adopt group was environmental, whereas for the early adopters, environmental was the least mentioned.

The early adopters reported two unique motivations absent in the yet-to-adopt group: community-driven and grid benefits. As early adopters, they had their own desire to engage LMI and experienced the push from communities to include LMI households. Early adopters recognized the potential for grid modernization and enhancements through projects that target areas that are often impacted most for grid benefits. Both groups identified responding to regulation and improving business development as LMI motivations. Market restructuring opportunities influence energy decentralization such that ownership of

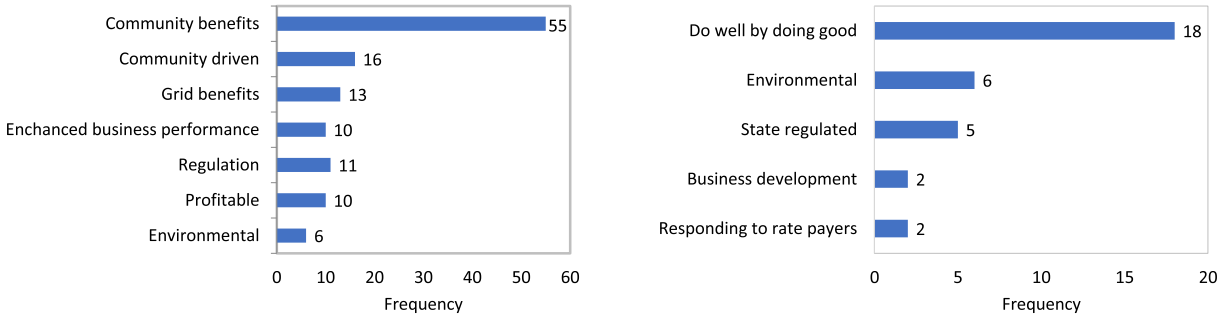

Fig. 11. Motivation for LMI participation – Left: Early adopters; Right: Yet-to-adopt.

distributed generation, in turn, affects energy decentralization (Hess and Lee, 2020).

Notice the low appreciation of environmental concerns in the early adopters surveyed. A notion exists that LMI communities have "bigger things to worry about." The notion is oversimplified, and growing environmental awareness and justice could be the bridge for additional CSP and LMI participation, especially when considering disaster recovery efforts via smart grids and distributed generation. Environmental concerns align with the workshop discussions, where greater connections were made to environmental and climate change policies as drivers of change. Considering the benefits of LMI as perceived by the yet-to-adopt in Fig. 12 demonstrates alignment with the motivations of the early adopters.

The survey offered pre-determined "benefit" choices, whereas "motivation" choices were open-ended, but public relations and goodwill are still the main benefits. However, as seen in Fig. 12, grid balancing is prioritized over cost. These rankings shed light on avenues of business and community education in efforts to increase LMI communities. It also shows the shifting role of grid balancing and when and where CSPs align with balancing efforts.

Nevertheless, motivations themselves do not solve or mitigate adoption barriers. For just over half of the early adopts, the decision to include LMI was "easy" to determine. The rest reported they had debated the prospects, with four organizations depicting their decision as controversial to pursue. In contrast, of the yet-to-adopt community that plans to invest in CSPs, there is an almost equal split of those intending to include LMI or not. Of the early adopters who did not have LMI projects, represented in Fig. 13, the majority indicated that financial issues were the leading cause, followed by technology challenges and lack of knowledge. Financial issues refer to lack of financing and investment losses with LMI inclusion. Technology challenges capture inadequate generation and available infrastructure in LMI communities (Lukanov and Krieger, 2019). Alongside motivation, the initiation of LMI projects is driven by community partner outreach, followed by regulation and utilities. Over 80% of responders designate these drivers as influential. Thus, successful adoption of LMI projects requires a

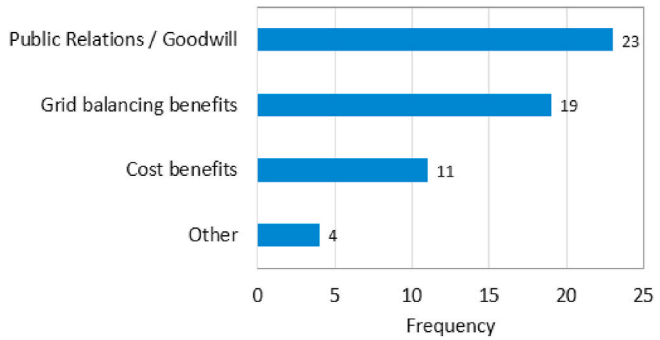

Fig. 12. Yet-to-adopt perceived LMI benefits.

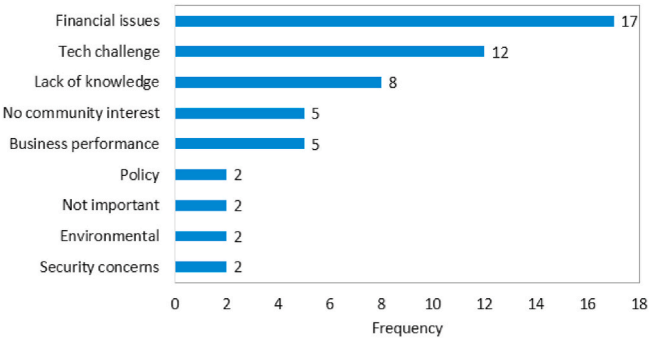

Fig. 13. Early Adopts perspectives on not involving LMIs.

three-pronged approach from each of these factors to their respective community outlets. The challenge with outreach partners is a perception issue with the yet-to-adopt group. Only around half, at 47%, plan to engage NGOs for LMI adoption, with 35% not anticipating it and 18% unsure. The distribution suggests additional attention in business and government education is necessary to train organizations yet-to-adopt the benefits of NGOs in community energy.

4.3. Strategic policies for CSP adoption

Policies play a substantial role in LMI inclusion. However, to what extent, and which policies have the most significant impact? For the early adopters, around 80% reported state and federal policies as influential in their decision to adopt CSPs and include LMI households. Fewer than 5% indicated that policies had any impact. Examining the yet-to-adopt perspective on state and federal policy paints a different picture. Regarding plans to include LMI, just over one third reported that policy would influence their decision to include LMIs, for both state and federal.

State and federal perspective break down the specific policies yet-to-adopt organizations identified. The open-ended responses for analyzed and grouped by themes, with the category breakdown observed in Fig. 14. Standards and regulation and financial support lead the way in policy significance for both federal and state perspectives. The primary regulations include a range of policies that assist in adoption practices, mandates, and incentives. On the state side, financial support groups state-provided grants, cost recovery mechanisms, and tax incentives. Federal financial support relates to additional funding sources, cost reduction, and tax benefits.

The second workshop panel focused on success stories, reinforced several perspectives and offered new ones. The summary findings, presented in Table 7, show that CSP and LMI need deliberate regulatory efforts. The reason is the slow progression of voluntary effort alone.

The idea is that policies targeting efficiency and modernization could act as catalysts for CSPs. The added contribution of the workshop on

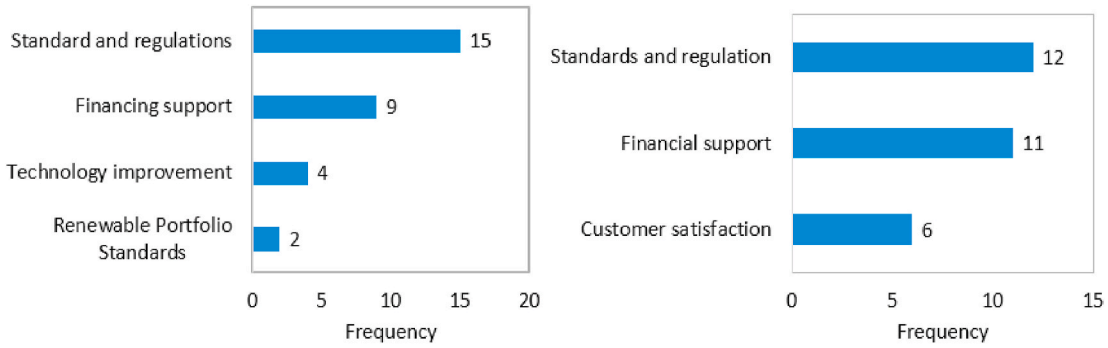

Fig. 14. Policies identified by Yet-to-adopt entities. Left: State. Right: Federal.

Table 7
Workshop Panel B on success stories: Summary of findings.

Question	Key Finding	Theme
What are your experiences and challenges?	Reducing LMI bills by 20-50%.	
	Subscription and interconnection burden.	
	Conflict of energy policy incentives.	
Differences in expectations and incentives?	LMI requires deliberate policy efforts.	
	Align with existing LMI energy benefit.	
	Efficiency and modernization.	
CSP drivers in areas without incentives?	Anchor customers, neighbor effect and pioneer corporations.	
	Culture shifts and collaboration.	

Standardization Interconnection Dynamic contracts Education and culture Efficiency and grid improvements

policies is the emphasis on aligning existing energy-benefit programs with CSPs and LMI inclusion. Relying on the experience of MN, CO, NY and DC that have already tapped into these funds, additional states should follow suit. Until the necessary new policies are enacted, stakeholders have found ways to adapt. In localities without incentives, several mechanisms have proven useful. First is the inclusion of anchor tenants to mitigate the lower credit scores of other subscribers. The concept of anchor tenants becomes integral to the new dynamic contracts necessary for CSP projects. By achieving the necessary risk security, CSP can support LMI and other customers that otherwise would be deemed financial risks for the overall project.

The second influence has been the neighborhood effect and adoption of pioneer corporations. When organizations see well-known corporations investing in solar and community energy, it sends a clear signal to the rest of the market on the viability and prestige of solar and supports the community in the process. A similar effect is observed within communities that learn of energy developments in their surrounding area.

The third contributor has been the product of sustained stakeholder education, causing culture shifts and more vital collaboration. Advocacy groups work around the clock to engage and align stakeholders, with the eventual outcome of persuading all necessary parties to change perspectives and pursue new practices. The long-term benefit is that the related parties become CSP proficient and make stronger collaborations in the future.

4.4. *Influence of the financial mechanism*

Given the range of financial barriers, a deeper dive into the financial support mechanisms is beneficial. As reported in Fig. 15, the top forms of financial support are financing tools and tax benefits that help reduce or

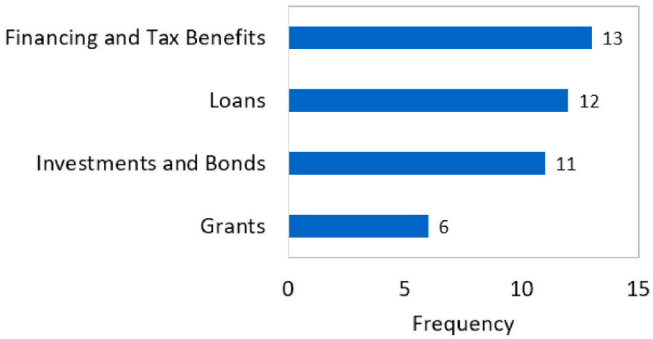

Fig. 15. Financial mechanisms to support CSPs given by the Yet-to-adopt CSP organizations.

mitigate the high capital costs. Close runner-ups include loans and investment opportunities to spread the upfront costs and increase return opportunities. These financial mechanisms include federal, state and bank specific financing options, revolving funds, and low-interest loans.

To expand CSPs into LMI communities, developers and utilities are required to account for diverse financial circumstances. Around 80% of early adopters indicated that LMI participants influence project financing methods. In contrast, the yet-to-adopt had an almost equal division between organizations that predict their financing method will change if LMI are included (35%), will not change (35%) and do not know yet (30%). The contrast between the two groups suggests a potential education and preparedness gap in organizations with yet-to-adopt LMI projects. To capture financial considerations, responders were asked how their financial decisions would change by including LMI communities. The primary observed difference between the early and yet-to-adopt groups is the emphasis, as depicted in Fig. 16. The top consideration would be to change the financing structure for early adopters, followed by business and project development practices. However, the yet-to-adopt identified their top consideration as financing, improved outreach, education and accessibility to LMI communities, and business development. Better outreach was also recognized in the early adopters but lower on the frequency ranking.

Financing decisions focus on rate structures that accommodate LMI and non-LMI customers, low-interest long-term loans, different fund allocation, and applying for government grants and tax incentives. The changes to business development would focus on management decision-making, streamline processes and LMI knowledge, improved business infrastructure for better staff motivation, customer service, and partnering with non-profits. For different project development decisions, organizations would prefer to reduce implementation time, lower the cost of inquiry, and focus on project locations.

The third panel focused on financial tools and delved into various related topics, summarized in Table 8. Again, pursuing economies of scale and anchor tenants were identified as playing a main role in mitigating the financial risk of longevity and recuperating project costs through their long-term participation commitment while allowing LMI customers to participate in the project as well.

A no-loan-loss reserve fund is a tool supported through green banks and other financial institutions. By offering to cover potential losses of LMI customers defaulting or leaving the project, the developer may still pursue a CSP by not losing recovery mechanisms until a new subscriber is replaced. Pooled funds relate to the collaboration of stakeholders to aggregate their funds and cover the LMI participation portion. Pooled funds do not imply LMI have no financial stake but rather that the upfront cost may shift to the general community. Supporting the ongoing participation may be achieved by two rate structures, one for general subscribers and one for empowered (LMI) subscribers.

States with enacted CSP-supporting policies see higher LMI participation rates. The message is evident in the workshop: there is an essential need to streamline and standardize financial tools and opportunities focusing on enhanced inter-agency coordination. Standardization should cover aligning incentives, goals and benefit programs. It has been argued that the policy-making process requires standardization for smart cities, particularly for energy efficiency (Anthopoulos and Giannakidis, 2016). A key contributor is federal aid and state-level LMI policies such as “Solar for All” and workforce partnership programs. The last item raised is addressing the challenge of interconnection and battery storage. For specific hybrid configurations with wind energy, battery investments have been shown only to become justified with higher levels of renewable energy (Baker et al., 2018). Interconnection for LMI projects still needs to be financed, adding another burden. Battery storage, however, was introduced as a driving factor that could make developers and utilities more inclined to build CSPs that support LMI through the value-added value stack of storage.

The 4th workshop panel on the future of CSPs sheds light on stakeholder engagement, as summarized in Table 9. The two items missing in stakeholder dialogue around financial mechanisms are.

education outreach across all levels and changing customer behavior and policies. Current CSP education and outreach are administered through advocacy groups and a pioneering group of developers, utilities and states. The effort must increase, especially on the large utility and municipality levels. The path to change customer behavior is long, but energy autonomy and literacy will be part of the solution to pushing for enhancing CSP policies. One of the final takeaways from the workshop was that the driver of change would be resiliency strategy and industry-wide collaborations. As regional grid infrastructure continues to be stressed by climate change, rising demand and severe weather events, states and utilities turn their attention to modernizing their grids with smart grids and distributed generation. This drive for resiliency could serve as a CSP catalyst where stakeholders collaborate on resiliency and public benefits.

5. Synthesis of the interviews, survey and workshop

This section, first, offers a synthesis of the identified factors of CSP adoption. Second, this section discusses how CSP market potential can be unlocked. The analysis brought forth reinforcing synergies and several contrasts of perspectives throughout the research phases.

5.1. CSP barriers and drivers

The three phases highlight several shared barriers and unique contributions, as shown in Table 10, alongside the ranking of the barrier within the phase. The interview phase highlighted the lack of economies of scale, absence of policies, aligning stakeholders, and suitable location as the main barriers. While the interview phase mentioned customer subscription and finance, these were not the top barriers. The survey added the components of subscription challenges, lack of developer and utility CSP knowledge, and a perception gap between the early adopters and yet-to-adopt on CSP processes. The survey reinforced the absence of economies of scale by isolating the financial viability concerns and further identified hindering policies. Most of the subscription barriers raised by the survey, however, were related to the LMI communities. The workshop continued to reinforce education, outreach and subscription,

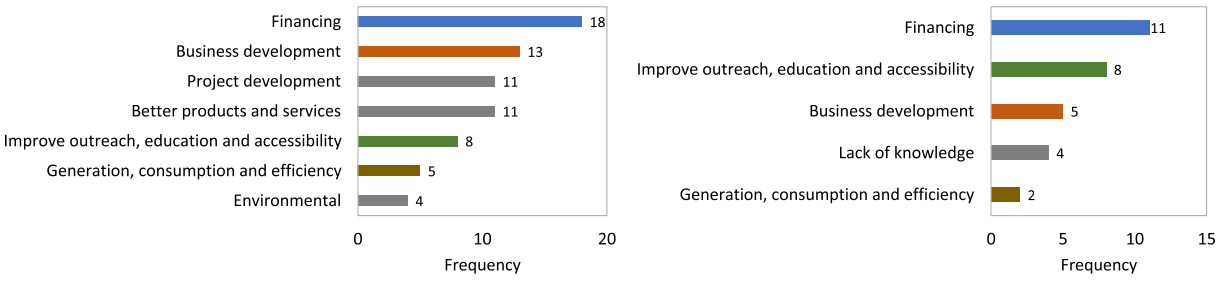

Fig. 16. LMI Financial considerations – Left: Early adopters; Right: Yet-to-adopt.

Table 8
Workshop Panel C on financing: Summary of findings.

Question	Key Finding	Theme
What are the financial mechanisms for CSP?	Anchor customers, no loan loss reserve, economy of scales, pool funds	
How to enable LMI participation?	Grants, tax credit, anchor customers, different market rates, Green Banks	
To what extent is policy intervention needed to increase LMI participation?	Essential to streamline and standardize	
	Design incentives, goals and benefit alignment	
	Federal aid, Solar for All, workforce partnerships	
How does LMI access vary in states with and without enacted shared solar polices?	Higher participation in states with enacted policy	
	Enhanced interagency coordination	
	Addressing Interconnection and storage	

Standardization Interconnection Dynamic contracts Education and culture Efficiency and grid improvements

Table 9
Workshop Panel D on discussion of the future: Summary of findings.

Question	Key Finding	Theme
What is missing in our dialogue?	Education and outreach across all levels.	
	Changing customer behavior and policy.	
What will influence change?	Resiliency strategy & industry-wide collaboration.	

Standardization Interconnection Education and culture Efficiency and grid improvements

lack of standardization and suitable location site. On top of these, the workshop introduced the interconnection barriers and competition with utility and larger-scale solar projects.

The main differences in barriers between the interview phase and both the survey and the workshop are the issues of customers and knowledge. Participants in both the survey and workshop reported customer subscription and financing models, and community and business education as main obstacles, but the interview phase did not. The difference should not be considered a discrepancy but rather attributed to a potential difference in perspectives. Most of the interviewees were developers of large-scale projects that have not yet transitioned to small and community-scale solar. The distinction could be reconciled by the notion that lack of economies of scale, and the dollar per kilowatt cost of installation, is their leading metric and that this group is not focused on the consumer side and their ability to secure subscribers.

The identified motivations and drivers also differed across the stages, visible in Table 11. The common themes identified in all phases were community benefits and grid modernization. Community benefits is an overarching term aimed at motivation to improve community well-being. Modernization and resiliency should be understood as encompassing enhanced grid performance, resilient distributed generation and enhanced regional energy strategy (Burke et al., 2019). For example, a key metric is the impact on the financial performance of the engaged utility (Gai et al., 2020). For phase 1, resilience and modernization focused on broader incorporation of battery storage in CSPs; the survey revolved around distributed generation strategy and grid balancing, and in the workshop on general modernization and investing in resiliency and social justice. Improved value stacking and sustainability have likewise been represented in multiple dimensions, further suggesting the potential of CSPs to be promoted in these avenues.

The interview phase focused on community benefits and the innovation advantages of introducing battery storage and improved value-stack to community projects. The focus on technology incorporation and value stacking was missing from the survey, only to appear again in the workshop. The differentiation in the workshop was the emphasis on resiliency and grid modernization as the goal, using storage and value stack as promising examples. The survey found that both early adopters and yet-to-adopt are keen on improving customer relations and include CSPs as part of their broader distributed energy strategy.

Additional drivers revolve around policy compliance and incentives (Mirzania et al., 2019). Sustainability, though lower in emphasis, is among the contributing influences. The workshop reinforced community benefits but added new dimensions. In states without favorable CSP policies, the main adoption enabling practices pursued by utilities and developers have been to plan for a portfolio approach of projects to achieve benefits in economies of scale, rely on anchor tenants, and invest in community and stakeholder education. Anchor tenants, neighborhood effect (where adoption is increased as more customers see others invest in CSP), and pioneer corporations lead to greater CSP participation. In areas without designated CSP policies, these factors were essential to the success of CSP projects and have been both an example for others to follow and an avenue for LMI participation.

Table 10
Summary of barriers of CSP adoption: The tick marks indicate a barrier at a phase, and the sequence represents the rank of that barrier in the phase. Question key maps the specific research questions from each phase that contributed to the finding.

CSP adoption barriers	Phase 1	Phase 2	Phase 3	LMI
Absence of economies of scale	✓(1)		✓(3)	
Absence of policies	✓(2)	✓(4)	✓(1)	✓
Stakeholder alignment	✓(3)			✓
Suitable project location	✓(4)	✓(5)		✓
Lack of CSP knowledge		✓(2)		
Financial viability	✓(6)	✓(1)		✓
Customer subscription	✓(5)	✓(3)	✓(2)	✓
Lack of standardization			✓(1)	
Education and outreach	✓(7)		✓(2)	✓
Interconnection burden			✓(4)	✓
Question key mapping	I.1 I.3	SA.2 SA.3 SY.1 SY.3 SY.7	WA.1 WA.2 WA.3 WB.1	I.3 SA.4 SA.5 SA.8 SY.5 SY.6 SY.7 WA.1 WA.3 WC.2 WC.4

Table 11
Summary of motivations/drivers of CSP adoption. The tick marks show the motivation at a phase. Question key maps the specific questions from each phase that led to the finding.

CSP Motivation and Drivers	Phase 1	Phase 2	Phase 3
Community benefits	✓	✓	✓
Resiliency and grid modernization	✓	✓	✓
Improved value-stack	✓		✓
Improving customer relationships		✓	
Policy compliance		✓	
Sustainability		✓	✓
Anchor tenants			✓
Neighbor effect & pioneers			✓
Education and culture change			✓
Question key mapping	I.1 I.2 I.4	SA.1 SA.6 SA.7 SY.2 SY.4 SY.8 SY.9	WB.2 WB.3 WC.1 WC.2 WC.3 WC.4 WD.1 WD.2

The workshop further emphasized that the future of CSP will be shaped by education and culture change, of both customers and organizations, and resiliency and grid modernization. A recent study showcases how strong utility-scale deployment helps build local PV competencies and ecosystems for improved solar value chains (Matsuo, 2019). In addition, successfully creating CSP-literate stakeholders will help influence bottom-up change from the customers' perspective and a top-down change from the organizations. Lastly, focusing on grid modernization as a driver, alongside distributed energy strategies, will serve as platforms for utilities, municipalities, and states to justify and integrate CSP into their plans.

5.2. Unlocking CSP market potential

The breakdown of adoption efforts identified throughout the phases is presented in Table 12. Two shared efforts are observed: a need for directing standards and regulations and community education. These two efforts translate to four themes that encompass all adoption efforts: community education and outreach, stakeholder education, standardization of larger project capacities and directed policy, and viewing CSPs as components of grid modernization and distributed energy policies. The contrasts between the phases are also important to consider, as summarized in Table 13. The interview phase focused more on profitability than customer relationships and dynamic contract options. Perhaps surprising given the emphasis on profitability, only one interview respondent raised the influence of interconnection. The survey, on the other hand, while repeatedly identifying financial viability, did not specify economies of scales or portfolio approaches to CSP developments. The survey provided a sharper distinction of perception differences between early and yet-to-adopt organizations, offering insight on future educational resources to focus on.

Based on early adopters, the role of third-party partnerships is critical for successful CSP implementation. The vast majority of early adopters report established partnerships with third-parties for various issues, including CSP development, customer outreach, education and sign-up, financing, managing CSP post-completion, and locating a host site. The workshop further elaborated on the type of contracts that would support CSP. These dynamic contracts include anchor tenants and shorter contract lengths for LMI and regular subscribers to mitigate financial risk and increase customer satisfaction. Lastly, the workshop emphasized environmental drivers, climate change and resiliency as areas needing additional considerations and drivers for CSPs.

6. Implications for LMI participation

LMI face similar considerations and thematic barriers to general CSPs but to a greater extent. The barriers are regulation, financing, education and subscription. These might be repetitive, but they offer the LMI perspectives.

Table 12
Synthesis of approaches to unlocking the market potential of CSPs.

CSP adoption efforts	Phase 1	Phase 2	Phase 3
Economies of scale	✓		
Standards & regulation	✓	✓	✓
Community education	✓	✓	✓
Project coordination	✓		
Grid modernization	✓		✓
Financial support		✓	
Improving customer relationships		✓	
Broader DE strategy		✓	
Interconnection			✓
Culture change			✓
Dynamic contracts			✓

Table 13
Contrasts and similarities in approaches to unlocking the market potential of CSPs.

CSP adoption efforts	Phase 1	Phase 2	Phase 3
Contrasts between phases	• Focus is profitability. • Customer relationships and dynamic contracts not identified as main drivers. • Environmental concerns not main driver. • Interconnection not identified as big obstacle, but cost neutrality is emphasized as grid modernization and broader DE strategy goal.	• Economies of scale, and portfolio approach are not identified as main drivers, through related though financial viability. • Distributed energy strategy is an important motivation, but greater grid modernization is not. • Misperceptions of yet-to-adopt on the challenges of project coordination, location, and LMI participation, with 3rd-level partnerships significant across CSP components.	• Environmental drivers emphasized to a greater extent than previous phases. • More focus on subscribers and dynamic contracts. • Additional attention to improve efficiency of customers, especially LMI, as part of any CSP project and supporting motivation.
Shared themes	• Community education and outreach. • Stakeholder education. • Standardize larger project capacities, CSP and LMI directed policy. • CSP component of grid modernization and distributed energy policy.		

6.1. Subscription and financial challenges

Developers and financiers worry about the longevity of contacts and the ability to secure LMI subscriptions. Subscriptions are difficult for CSPs to market and sell. Proactive education outreach on the benefits of CSP is the gateway to introducing LMI to the CSP market. The financial concerns go hand in hand with subscription challenges. One dimension of these is credit worthiness, often measured through credit and FICO scores which financers review as risk factors. Anchor tenants and programs that maintain the subscription benefits based on location and not on specific customers should be explored to overcome the financial risk. Anchor tenants play a big role in reducing the risk and creating no loan loss reserve. Using anchor tenants and variable off-takers is a way to guarantee standby and fully subscribed options. The anchor tenants become the main criteria for credit worthiness and FICO scores, allowing the participation of LMI households. On the location benefits, if a customer chooses to leave their current residence and therefore CSP, the CSP can transfer the subscription to a new customer moving in.

6.2. Regulation

There is a genuine challenge in maintaining LMI rates when cost neutrality and parity are the goals. Aside from consumption rates, the interconnection cost is another burden for LMI members that needs to be incorporated in cost mitigation efforts. The idea is to spread or mitigate the large upfront cost. As some LMI households struggle to pay their utility bills, the opportunity here is to lower their costs through inclusion in CSPs, creating a win-win situation when CSP incorporates efficiency upgrades and battery storage that benefit the community. One way to enable LMI rates is by linking efficiency and weatherization subsidies to CSPs. The idea is to expand the qualified subsidy offering to include participation in CSP and use the money to offset the rate for the providers. Another approach to increasing LMI participation is to couple LMI-included CSPs in future grid modernization, disaster and emergency management planning. Community programs that integrate microgrids and battery storage are essential components of grid modernization and resiliency efforts. This would further mitigate the disenfranchisement of LMI households, who are disproportionately impacted by climate change and inadequate grid services. In addition, doing so would further advance the business adaptation of utilities, developers and financiers to address LMI inclusion.

6.3. New business models

Deliberate project design and incentive structures for LMI are essential to overcome hurdles and streamline CSPs. Customer engagement is important, and building trust for subscriptions takes time. The challenge is that subscriber and developer perspectives do not necessarily align. For a developer, the utility-scale is more financially attractive than community solar. This can be mitigated by pursuing smaller projects as part of a portfolio approach to strategic economies of scale. With the growing support for LMI advocacy across the U.S., a holistic approach is necessary to bridge concerns and opportunities. Community energy is not about solving power struggles but about the problems customers face and identifying opportunities that community energy projects can address. Commercial, industrial and residential sectors could support LMI projects by acting as anchor tenants, but education for everyone involved is the key. A unique area to explore is the inclusion of battery storage to LMI and CSP projects as the novelty that financiers, developers, utilities, and customers can all benefit from.

7. Recommendations

The following are recommendations for stakeholders and policymakers to unlock the market potential for CSP. They form the backbone of the synthesized research analysis and shed light for policymakers and energy stakeholders on where to invest their effort and resources. These recommendations would also serve as roadmaps to mitigate the perception gap between yet-to-adopt and early adopters.

7.1. Scale of projects and portfolio approach

A significant factor to developers is the scale of projects, where small-scale projects are deemed financially unworthy. Small scale projects require comparable amounts of logistical and administrative effort in site surveying, zoning, procurement and customer acquisition as medium and large projects, resulting in a lower return on investments. Two solutions are recommended: portfolio approach and changing regulation to allow larger generation capacity. Lifting size limitations and encouraging entities to develop a portfolio of projects will provide multiple advantages, including the ability to: (1) realize the economies of bulk purchases of equipment; (2) develop the expertise and experience needed to reduce installation costs; and (3) spread the overhead and “soft costs” over more megawatts of producing assets.

7.2. Community education, project coordination and site location

Communities must be educated on the value and potential benefits of CSPs. Most customers are not familiar with community energy, and additional outreach is necessary to engage with communities and gather political and utility support. The education campaigns must address the financial benefits to customers and long term environmental and resiliency benefits. Alongside education, it is essential to include community project developers in the decision process. The challenge is coordinating between utilities and city officials, as the range of policies and regulations can be broad and uncertain. Of main import is determining the project’s location and allocating space early in the project development decision process. Projects that delayed the location question have

experienced significant delays in permitting, clearances, and evaluations. Strong engagement is needed among developers, customers, utilities, and governments to overcome the education and coordination gap. The engagement would aid in assessing community needs and developing educational tools and strategies for subscription, location finding and related affairs.

7.3. Grid modernization, cost neutrality and efficiency

Community solar has a unique opportunity to act as a catalyst for grid modernization via distributed generation and when integrated with smart grid implementation. CSP complements grid modernization plans that seek to strengthen the resiliency of the distribution system. The increased resiliency is achieved by providing voltage and frequency support or a source of distributed generation that can be deployed during periods in which portions of the grid are islanded to support energy uses within the islanded section. Under these benefits, utilities and PUCs should consider integrating CSPs into their overall grid modernization plans and increasing CSP adoption.

Promising opportunities for CSPs are the dropping costs of battery storage, making storage a financial and strategic decision that will only create a stronger grid and increase the value stack of projects. However, there remains the question of cost neutrality and costs shifting downstream to other consumers or non-adopters. Considering CSPs as a joint effort of public, private and utility interest could align perspectives and promote participation and willingness to invest in a resilient future. Alongside modernization and cost neutrality, efficiency should not be overlooked in CSPs. Efficiency improvements often take priority in energy projects as an effort to reduce demand-side consumption and project size. Some utilities push for efficiency first, while others focus on renewables. There is a need to balance both efficiency and increased adoption of CSPs, as the investments will result in higher benefits. The idea is to bridge CSPs with efficiency upgrades for the subscribers and tackle both benefits simultaneously for the greatest impact on LMI communities which often include low-efficiency buildings.

7.4. Standardization

Standardization has been identified as a significant challenge throughout the industry. Standardization includes regulation, tax policy, metering, financing, infrastructure, and workforce education throughout different states, utilities, and companies. These pose a challenge as there is a lack of unified or integrated standards covering finance structure, processes, generation capacity, and interconnection. An added dimension to standardization is the question of credit and ownership of benefits between developers and off-takers.

To standardize CSP is to standardize its' components: interconnection, organizational structures, recruiting subscribers, securing locations, creditworthiness evaluations and assessments of the financial viability of projects, and process coordination and contracts. Current CSPs rely on existing expertise and local efforts of those interested in learning during the process. As CSPs continue sprouting around the country's distribution systems, the need for standardized procedures and processes is key, despite the decentralized nature of the industry. The future could see the formation of community energy standards that would operate in a similar fashion to renewable portfolio standards or the Solar Garden's PUC initiative in MN. A recurring aspect of the dialogue has been the standardization of both community education and technical standards and workforce training and certification. Currently, there is a general lack of specialized personnel within utilities, governments and community-based organizations pertaining to CSPs; in other words, standardized occupation of CSPs. Outreach, training, and education will be prerequisites of future successes.

7.5. Interconnection

Interconnection is a substantial financial burden and barrier to CSP adoption. While the price of land is often considered the main challenge to secure a location for CSP, it is not always the case. The question can be boiled down to "who should pay for interconnection?" or "how should interconnection costs be spread?". These costs vary by state and utility, and when they amount to tens of thousands of dollars per project, they may simply weed out small-budget projects that otherwise could implement CSPs and redirect the money saved for additional projects. Interrelated challenges include contracts and subscriptions, which offer both barriers and opportunities to spread the cost burden of interconnection. The current questions include whether improvements in grid performance resulting from the increased inclusion of large-scale storage will reduce interconnection costs. Standardizing the spread of interconnection costs, which need further attention with LMI projects, will greatly increase the adoption of CSPs by removing a substantial financial obstacle.

7.6. Dynamic contracts

A recurring challenge for CSP adoption is contract length and subscription. Coops and wholesale providers can push for longer contract terms, such as 25 years, and investors push for minimizing financial risk. However, communities and tenants may be wary of long contracts or lack required credit worthiness. Complicating matters, as the location of CSPs may be a commercial rooftop or farmland, there are additional stakeholders involved that have their own concerns and requirements. Thus, dynamic contracts that include anchor tenants and shorter terms for relevant populations have an important role in identifying and mitigating risks for all stakeholders involved. Having anchor tenants will ease the risk for developers and financiers and enable additional variability to shorten customer commitment. This would serve the range of customer types, those with and without credit worthiness challenges. There is an important opportunity for large corporations to act as anchor tenants throughout their geographic locations and secure the benefits of portfolio approach for economies of scale and allow additional customer subscriptions. Contracts that enable these dynamic customer and timeline conditions would align businesses and communities by diversifying the risk and increasing opportunities for everyone.

8. Policy implications and conclusion

The growing interest in CSP has primed the energy market and stakeholders to tackle the myriad barriers and opportunities in the energy ecosystem. The academic field has rich discussions and efforts to understand CSPs, and our research findings align with several of the existing barriers documented in the field. Our contribution to the field is the result of a three-phased methodology that created, on the one hand, a broad platform to encompass almost the full range of stakeholder representation, and on the other the ability to critically dive into specific groups and themes. Understanding CSP barriers and drivers and how to unlock the market potential have shaped the entire methodology and analysis process.

Examining the barriers and drivers of the stakeholders in the CSP ecosystem brings us one step closer to realizing the market potential through increased adoption and improved access. To provide the adequate platforms for CSPs to flourish, change is necessary across all levels. From the top level, federal and state institutions must pursue policy changes that standardize practices, incentivize participation, and in collaboration with financial mechanisms, spread the financial burden. To borrow from the success of renewable portfolio standards and the increase in voluntary green power, policies should examine the role of mandating and incentivizing CSPs. Formalizing financial opportunities for reducing the financial burden through loans, revolving funds, grants, and investment opportunities will pave the way for small and medium-

sized developers and communities to tap into CSPs. Policies should focus on federal CSP and LMI support, partnerships with workforce developments, refinement of CSP and LMI processes, and standardize best practices.

Top-level changes are not enough, however. Industry stakeholders share the challenge of customer and business education and the long road to increase subscriptions. Local and community efforts must focus on education campaigns for the benefits of CSPs, with additional emphasis on LMI communities. Tailoring policies that streamline standards, mitigate interconnection costs, design dynamic contracts and incorporate grid modernization and efficiency will build the successful platforms to pursue CSPs. A substantial driver of change is providing the opportunity to enjoy the benefits of economies of scale. The future requires long-term business and energy strategies for developers, utilities, municipalities, and communities. These are achievable when stakeholders convene to share goals and concerns and create a roadmap for success based on portfolio approaches.

In line with top-down and bottom-up approaches to unlock the CSP market potential, future research should explore subscribersâ€™ response to education campaigns and outreach efforts. As a recurring barrier throughout the CSP ecosystem, understanding why some educational efforts were more beneficial than others would help tailor future education methods and materials. Such a subscriber-centered study could also benefit from a multi-phase methodology focusing on the existing CSP customers, especially LMI, and potential customers. The methodology should be aligned with generating material appropriate for household consumption and advocacy groups, power providers and municipalities. Utilities are an important contributor to the future of widespread CSPs and LMI participation. When businesses, developers and policymakers embrace community energy, utilities can serve as key collaborators by balancing stakeholders' interests with strategic planning aligned with local and federal government policies. With the presented barriers and opportunities for broad CSP adoptions, policymakers, power providers and communities can collaborate and pursue the system-wide benefits of community energy projects.

CRediT authorship contribution statement

Dor Hirsh Bar Gai: Formal analysis, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Ekundayo Shittu:** Conceptualization, Methodology, Formal analysis, Data curation, Investigation, Visualization, Supervision, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition. **Donna Attanasio:** Conceptualization, Investigation, Writing – original draft. **Carmen Weigelt:** Conceptualization, Investigation, Writing – original draft. **Saniya LeBlanc:** Investigation, Writing – original draft. **Payman Dehghanian:** Investigation, Writing – original draft. **Scott Sklar:** Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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