Who Gets Watt? Institutional Analysis of Four Community Solar Programs in the U.S.

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ABSTRACT

Solar energy systems purchased in the United States have increased tenfold since 2010. As solar photovoltaics (PV) markets expand, solar energy becomes more affordable. In the last five years, the price of solar has decreased by 40 percent. Despite solar PV becoming more affordable and rising consumer demand, between 50 percent of U.S. utility ratepayers are unable to install rooftop solar due to a number of obstacles including financial barriers and lack of rooftop ownership. One way to diminish this lack of access is through community-based solar energy programs, which have been able to overcome some of the barriers to consumer participation in the solar PV market. Community solar policies have emerged as a new form of solar financing model mandated by legislative policies in 15 states with a combined energy capacity of 1,387 installed megawatts. The intended goal of community solar is to expand solar PV access to those who were previously unable to participate in the solar PV market. Existing solar community choice programs have shown a lot of heterogeneity in terms of program design and implementation. This has created an opportunity to reflect on the institutional design of community solar programs to better understand the extent to which program design impacts residential and low-income participation. This study utilizes Ostrom's Institutional Analysis and Development (IAD) framework to examine institutional arrangements of community solar programs in Minnesota, Colorado, New York, and Massachusetts. It employs a qualitative content analysis of the laws and regulations in place, along with semi-structured interviews of 16 program stakeholders to determine what aspects of program design lead to greater residential and low-income participation. The findings suggest that institutional design of community solar programs impacts who benefits from the program. The most critical components of community solar program design for residential and low-income

access are: who administers the program, a balance of residential and commercial subscribers, higher incentives for residential and low-income subscribers, and a clear and predictable incentive design.

I. Introduction

Renewable energy generation in the United States has doubled in the last ten years, with 382 million megawatt-hours (MWh) generated in 2008 and 742 million MGh generated in 2018 (U.S. Energy Information Administration [EIA], 2019). Almost 90 percent of the increase in renewable energy generation between 2008 and 2018 came from wind and solar power (EIA, 2019). Wind generation rose from 55 million MWh in 2008 to 275 million MWh in 2018 and contributed to 6.5 percent of total electricity generation (EIA, 2019). Solar energy provides the third largest renewable energy power source and accounts for 2.3 percent of total electricity generation (EIA, 2019). Solar has lagged behind wind energy generation, but the growing price reduction in solar PV modules and favorable policy incentives has facilitated a rapid growth in annual solar PV installations. Solar generation has increased from 2 million MWh in 2008 to 96 million MWh in 2018 (EIA, 2019). The United States electric power sector plans to add more than 4 GW of new solar capacity in 2019 and almost 6 GW in 2020, a total increase of 32 percent from the operational capacity at the end of 2018 (EIA, 2019). Over the next five years, total installed capacity of solar energy systems is predicted to increase by 50 percent, reaching 100 gigawatts (GW) by 2021 (SEIA, 2019).

As solar PV markets expand, solar energy is becoming more affordable and cost competitive. In the last ten years, the price of solar has decreased by more than 70 percent (Solar Energy Industries Association, 2019). Despite solar PV becoming more affordable and rising consumer demand, an estimated 50 percent of electricity consumers in the U.S. are unable to install rooftop solar due to financing constraints and lack of suitable rooftop ownership (Feldman & Margolis, 2015). One way to diminish this lack of access is through community-based solar energy programs, which have been able to overcome some of the barriers to consumer participation in the solar PV market. Community solar policies have emerged as a new form of state-based solar financing model mandated by legislative policies in 15 U.S. states. Community solar is a form of distributed generation (DG) that involves solar garden arrays that can be owned by a private firm, investor-owned utility, public-owned utility, or a non-for-profit organization. The total generation capacity of the solar array is allocated to participating subscribers that can include businesses, nonprofits, commercial, industrial, and residential utility ratepayers. The subscribers are often compensated for their participation in the program by receiving a credit on their utility bill. In states with mandated community solar legislation, the policy rules dictate community solar program design and who can participate and benefit from the program. Community solar programs provide an alternative option to rooftop solar, and have been designed to increase access to solar energy and reduce upfront costs for participation (NREL, 2019; Bonneville Environmental Foundation, 2013). As of 2018, community solar projects contribute to 1,387 MG of installed solar capacity and are expected to add an additional 3 GW in the next several years (SEIA, 2019).

IAD and its relevance: The heterogeneity in program design across states has created an opportunity to compare the institutional design of community solar programs, based on regulations, incentives, and program arrangements. The Institutional Analysis and Development (IAD) framework lends itself well for this type of analysis because it offers a conceptual map by which to examine the rules and actors that shape institutional design and the outcomes that result from these institutional arrangements. Utilizing the IAD framework, this research is seeking to examine institutional differences in community solar programs to understand the extent to which institutional design promotes solar access for residential and low-income customers. It employs a qualitative content analysis of the laws and regulations in place, along with semi-structured interviews of 16 program stakeholders to determine the extent to which these programs address the issue of expanding residential and low-income access in the solar PV market.

Section II provides a literature review with a focus on renewable energy policy, existing barriers to renewable deployment, and recent policy innovations to address these barriers. Section III presents the Institutional Analysis and Development (IAD) framework used in this paper to identify variables and organize research analysis. Section IV discusses the methods used. Section V presents background information on each state community solar program followed by an analysis that is organized by key facets of the IAD framework. Section VI summarizes the research findings and policy considerations.

II. Literature Review

A. U.S. renewable energy policy

Interest in alternative energy sources developed in large part in the U.S. due to the 1973-74 oil embargo and rising energy costs (Hitaj, 2013; Sen & Ganguly, 2017), while more recently it has been driven by climate concerns and military conflict in the Middle East. Renewable energy is rapidly growing in the United States due to declining costs and favorable policies at the national, state, and local levels (EIA, 2019). Policymakers have incentivized renewable energy deployment through regulations and financial incentives that have expanded consumer choice and kept electricity prices low by creating competition (Menz & Vachon, 2006; Micaud, 2018). They have also sought to drive (1) decentralization (2) security, (3) diversification, (4) and decarbonization (Carley & Browne, 2013). Wind power has experienced substantial growth (96,433 MW of installed capacity in 2018 and 6.5% of total electricity generation), while solar is playing a smaller, but still important role in the growth of renewable energy deployment (EIA, 2019). Recent advancements in photovoltaic technologies combined with federal and state incentives has significantly reduced the cost of investment and contributed to the rapid growth of the solar PV industry (Hagerman, et al., 2016). From 2010 to 2018, there was a 63 percent reduction in the cost of residential solar PV systems and 66 percent cost reduction in commercial systems (Fu et al., 2018). Significant price reduction in solar PV mostly due to falling hardware costs (SEIA, 2018), and the cost of modules is expected to continue to drop, falling below $0.20/W in the next five years (Feldman & Margolis, 2018).

i. Financial incentives

At the federal level, the National Energy Act of 1978 established the Energy Tax Act, which created a program of tax credits for households and businesses to offset the cost of purchasing alternative energy equipment (International Energy Agency, 2013). The program established the first residential investment tax credit (ITC), which gave a 30 percent ITC for the first $2,000 spent on solar and wind energy equipment and 20 percent ITC for the next $8,000 spent (Jones & Bouamane, 2012). The program also created a 10 percent ITC for businesses to invest in various renewable energy sources including wind, solar, and geothermal (Jones & Bouamane, 2012). The Energy Tax Act was relaunched under the Energy Policy Act of 2005 to provide 30 percent ITC for residential and commercial customers with residential credits capped at $2,000 (Stokes & Breetz, 2018). ITC has been extended through 2022 for solar PV but the incentive will decrease to 26 percent after 2019 and 22 percent after 2020 (Augustine & McGavisk, 2016). Federal tax and financial incentives have also played an important role in encouraging wind power development (Hitaj, 2013). The Energy Policy Act of 1992 established the production tax credit (PTC), which provides the investor or owner of an eligible system with an annual tax credit of 1.5 cents/kWh based on the amount of electricity that is generated by the system (Gouchoe et al., 2002). This type of incentive works to maximize renewable energy output by crediting qualifying wind generators an inflation-adjusted PTC during the first 10 years of project operation (Bird et al., 2005; Hitaj, 2013). The PTC was originally available for projects installed between 1994-1999, but over the years has received several extensions (DSIRE, 2018). The PTC encouraged rapid deployment of wind power facilities by adding an annual rate of 1,400 MW of wind energy capacity in the U.S. (Shrimali et al., 2015).

Complementing federal production and investment tax credits, state governments have taken actions to increase renewable energy capacity and generation, with many states providing financial incentives to encourage the use of renewable energy in their state (Shrimali & Kniefel, 2011). State financial incentives take many forms including tax incentives, grants, loans, rebates, and production incentives (Delmas & Montes-Sancho, 2011; Menz & Vachon, 2006). Fifteen states finance these incentives with public benefit funds (PBF), which is a form of trust fund that is financed by customer electricity bills (Menz & Vachon, 2006). The research to date has found a positive relationship between financial incentives, usually tax credits, and deployment of solar PV technology (Sarzynski et al., 2012). The most common finding on the effectiveness of energy tax incentives is that they are best and most often used in a supporting role to other policy instruments. Also, tax incentives have been found to effectively promote the development of small-scale renewable installations (Carley & Browne, 2013). The main goal of these federal and state incentives is to diminish financial barriers and make renewable technologies competitive with or more attractive than conventional electricity (Menz & Vachon, 2006).

ii. Mandates

At the federal level, there has been a series of policies that have been enacted to allow for the growth of renewable energy markets. The passage of the Public Utilities Regulatory Policies Act (PURPA) in 1978 set the stage for utility deregulation by requiring utilities to purchase power from qualifying facilities. Moreover, the Energy Policy Act of 1992 allowed utility and non-utility firms to own independent power generators, which allowed independent firms to participate in the wholesale power market and contribute to the growth of renewable energy (Delmas & Russo, 2007). In 1996, FERC issued Order 888, which required non-discriminatory access to generation lines owned and operated by utility firms, which gave independent power producers (IPP) access to the grid to transmit energy, including wind and solar power. Starting in 1998, retail deregulation in electricity markets began with several U.S. states, including California, New York, and Massachusetts, allowing for competition in the electric power market. Utility deregulation paved the way for consumer choice to select energy providers and keep energy prices low by stimulating competition (Michaud, 2018; Federal Trade Commission, 2007).

Renewable energy growth in the United States can be largely attributed to state-based policies. States have adopted several statutory and regulatory mandates to promote renewable energy deployment. One of the most prominent state-based policies is the renewable portfolio standard (RPS). RPS policies can be mandatory or voluntary and require a percentage of state's electricity to come from renewable energy by a certain date. (Stokes & Breetz, 2018). In recent years, some states, such as California, New York, and Oregon, have amended these policies to raise their RPS targets, and in the cases of California and Hawaii, policy requires 100 percent of all generation by 2045 (Hawaii PUC, 2018; California PUC, 2018). RPS policies share the common goal of encouraging renewable energy capacity, but the policies differ in design including percentage requirements, timelines, and qualifying renewables (Menz & Vachon, 2006; Wiser et al., 2008). For most states, RPS apply only to private electricity providers and in some states RPS can be met only through new renewable investments (Menz & Vachon, 2006). State RPS policies usually allow utility companies the choice to either generate electricity from renewables themselves, or pay to receive renewable energy credits (RECs) from private firms that produce energy sourced from renewables to meet state-specific RPS mandates (Carley, 2009). A REC is presented as package of environmental benefits resulting from avoiding emissions associated with a conventional power plant. These environmental benefits can be packaged into a REC and sold separately from the electrical power. A monetary value of REC is created when a megawatt-hour of RE is generated (Wiser et al., 2008). Some states with solar PV growth goals have established a solar specific REC called SREC, allowing solar PV system owners to sell their SRECs through an SREC market to utilities (EnergySage, 2019). In some cases, the future rights of RECs are sold up front on a per installed watt basis (NREL, 2011).

REC transactions create a revenue stream for renewable energy generators (Wiser et al., 2008). The monetary value of RECs often depends upon the demand and therefore future value can be uncertain (Drury et al., 2012). Many of the RPS policies also require generation disclosure by the utilities to their customers of the fuel sources used and associated emissions (Menz & Vachon, 2006). Currently, 29 states and Washington DC have implemented RPS (Hagerman et al., 2016). The effectiveness of RPS policies on the growth of wind and solar energy industry has been studied extensively with mixed findings (Langniss & Wiser, 2003; Yin & Powers, 2010; Eastin, 2014). Generally, the design of the policies determines the effectiveness of the policies on renewable energy generation (Yin & Powers, 2010). National Renewable Energy Laboratory (NREL) finds that RPS policies are more effective in driving renewable energy generation when they are combined with PTC (NREL, 2019).

In addition to RPS, many states have mandated net-metering (NEM) requirements for their utilities. NEM is a billing mechanism between utility providers and their residential and business customers who produce their own energy with qualifying renewable sources, such as solar PV. NEM policies require the utilities to pay for excess electricity generated by small-scale residential and business energy system owners (often at the full retail rate). As a policy option, NEM makes renewable energy technologies more economically attractive without requiring public funding

(Wan & Green, 1998). NEM provides an incentive to invest in small-scale solar PV and other RE systems because it allows distributed-generation (DG) systems to offset their energy expenditures and receive payment for excess generation (Heter et al., 2014). NEM quickly diffused to other states as a policy tool to encourage investment in renewable energy sources. As of 2014, 43 states have adopted mandatory NEM policies (Heter, 2014). The number of residential and commercial NEM customers has grown from 155,921 in 2010 to 1,727,698 in 2017 (EIA, 2017). As with most RE state policies, NEM policies differ from state to state in the technologies eligible to net-meter, the system sizes, how net excess generation is credited, and the aggregate capacity limits (Heter et al., 2014). Many utilities have criticized this compensation scheme as unfair to their other ratepayers, as customers with onsite generation are paid the full retail rate per kWh while the utilities remain responsible for the costs of maintaining the grid. Perez et al., 2016 argue that NEM is not reflective of location, PV design attributes, market penetration, and financial transactions that bypass the grid operator. The traditional design of NEM policies does not reflect the full net value of costs and benefits created by solar generation. Consumers who receive NEM from a utility do not contribute to the cost of maintaining the grid and transmitting electricity, which results in those costs shifting to the non-solar consumers (Perez et al., 2016; Wood & Borlick, 2013). As a result, NEM is now facing legislative amendments in 33 states to address the inadequate cost recovery scheme (Woo & Zamikau, 2017). Value of solar (VOS) has emerged as one potential alternative to NEM. VOS considers economic, regulatory, and environmental costs subtracted from benefits to determine the rate at which utilities credit solar energy producers (Welton & Eisen, 2018). Another policy alternative implemented by New York state is the Value of Distributed Energy Resources (VDER), which takes into account a number of added values (location, time of use, environmental benefit, etc) with the goal of more accurately compensating renewable energy generation.

Another type of state-based policy instrument to encourage RE production is requiring electricity suppliers to offer their customers green power options (NREL, 2017). These mandatory green power options (MGPO) allow utility customers to purchase green electricity blocks derived from renewable sources for an extra cost (NREL, 2017). In 2017, green power purchases represented 26 percent of all U.S. renewable sales (excluding hydropower), which translates to three percent of all retail electricity sales (NREL, 2017).

B. Barriers to solar PV access

Despite available incentives for solar PV investment, many residential and business customers are still unable to gain access to solar PV because they rent, live in multi-tenant buildings, have roofs that are unable to host a solar PV system, or experience some other mitigating factor (SEIA, 2018). Literature has demonstrated robust evidence of various barriers that still exist to consumer solar PV access: (1) financial, (2) informational/knowledge (3) institutional, and (4) behavioral. The National Renewable Energy Laboratory (NREL) estimated that 49% of households and 48% of businesses are unable to host a PV system either because they rent or do not have a suitable roof, leaving a large portion of potential solar PV market untapped. To date, the majority of renewable solar capacity has been installed at commercial, governmental, utility, and other nonresidential facilities. As of 2011, residential installations only accounted for 20 percent of installed solar capacity even though the residential sector holds 53 percent of potential solar PV capacity (Griffith et al., 2014). If the full potential of solar PV energy is to be realized, policy needs to address barriers that still exist for residential customers.

Previous research has often cited lack of financial resources and the high upfront cost of solar PV systems as a major barrier to solar PV adoption (Palm, 2018; Balcombe et al., 2013; Karakaya & Sriwannawit, 2015). In 2019 the average installed cost for a residential solar PV is $2.70 per watt DC (Wdc) and the average system size for residential customers is 6 kilowatts (kW) (NREL, 2018). This means that the average installed residential solar panel system would cost $12,516 after applicable tax credits (EnergySage, 2019). In addition to the high capital costs of solar PV systems, the average 7.4 year payback period is perceived as being too long (Balcombe, 2013; NREL, 2018). The diffusion of PV systems is also affected by the cost of other energy sources because customers often choose between PV systems and conventional sources of energy. If the costs of competing sources are low, these can constitute a barrier to PV adoption (Karakaya & Sriwannawit, 2015).

Another emerging field of research regarding solar PV access is focused on low-to-moderate (LMI) customers. This group has increasingly received more attention because in the U.S. LMI customers compromise 40 percent of the population whose annual income is $40,000 or less. Some of these barriers include access to financing due to low or lack of savings, less income to borrow against, less tax credits, and lower credit scores that further reduce access to affordable capital (Mueller & Ronen, 2015).

Another barrier cited within research is the lack of access to proper information and resources (Pelenur & Cruickshank, 2012). Literature suggests that lack of information about available renewable electricity programs serves as a barrier to consumer participation in these programs (Borchers et al., 2007), (Bird & Lokey, 2008), (Salmela & Varho, 2006). The need for heavy marketing is encouraged by research studies because consumers often are not aware that renewable electricity service is available in their area. Bird and Lokey (2008) recommend intensive marketing and education campaigns to address this consumer barrier into the renewable electricity market. Consumers require a lot of initiative and time to seek out information on their own to compare electricity options and costs (Salmela & Varho, 2006).

Customer perceptions of technological complexity has a large impact on their decision whether to adopt a new technology or not (Karakaya & Sriwannawit, 2015). Additional knowledge barriers include perceived technological risks, system reliability, and system maintenance (Balcombe et al., 2013). Awareness and adequate knowledge of programs and resources available to various stakeholders is necessary for informative decision-making in adoption of solar PV and the overall costs and benefits of the system (Yaqoot et a., 2016).

Institutional barriers arise when the government, utility companies, or bureaucratic rules impede customers from installing solar PV (e.g. eligibility requirements) (Reames, 2016). For example, many energy financing and program participation require strong credit profiles with a minimum FICO score of 700, which could preclude as much as 47 percent of U.S. households from being eligible (Drury et al., 2012). Institutional barriers could also arise when government incentives are incorrectly targeted or when utility companies refuse to promote solar PV options (Pelenur & Cruickshank, 2012).

NREL estimates that 49 percent of households and businesses are unable to host rooftop solar PV because they have aging roofs or roofs that are shaded by trees (Augustine & McGavisk, 2016). Households that own their properties also face challenges with rooftop solar installations.

According to an NREL analysis, only about 22 percent of residential building roof areas in cooler climates and 27 percent of residential rooftop rooftops in warm climates are suitable for solar PV (Feldman, 2012).

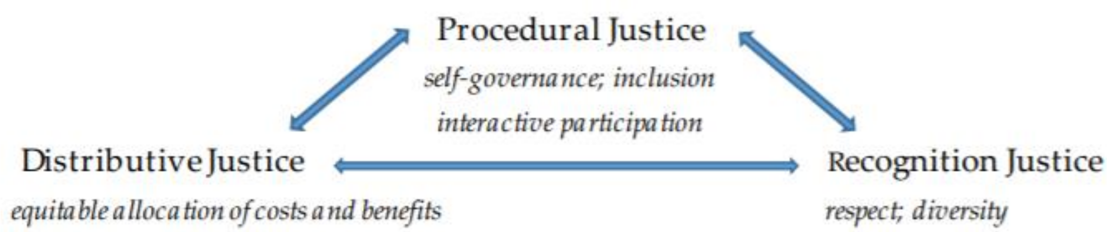
Another key challenge to households that rent properties or live in multifamily housing is the lack of control to make energy decisions (Cook & Bird, 2018). This type of barrier is an example of the principal-agent (PA) problem that arises when one person, the agent, performs tasks on behalf of another individual or the principal, but those tasks misalign with the principal's best interest. The PA problem involves transaction costs, asymmetric information, and split incentives typically between a landlord and a renter (Murtishaw & Sathaye, 2006). Extensive research has focused on the PA problem in the energy-efficiency sector (Bird & Hernandez, 2012; Pelenur & Cruickshank, 2012; Vernon & Meier, 2012). For example, a landlord may forego adding insulation to a building if the tenant is responsible for paying the heating bill. Home renters may have difficulty conveying the benefits of upgrading energy systems such as installing more efficient technologies because these technologies and their future energy use does not impact the landlord. In the case of solar PV, households who rent lack the control to make decisions regarding solar PV installations and the landlord would have to be involved for any on-site projects (Cook & Bird, 2018). Murtishaw and Sathaye (2006) estimated that 35 percent of residential energy is affected by the principal-agent problem. Another category of barriers to solar PV adoption are associated with consumer behaviors. Research indicates that some consumers perceive investments in solar PV as risky or uncertain (Horváth & Szabó, 2018). Another barrier is simply consumer mistrust that the system will perform as desired (Reames, 2016; Palm, 2018). The perceived complexity and inconvenience associated with switching energy systems is another behavioral barrier that keeps consumers with their default system (Palm, 2018). Status quo bias theory aims to explain people's preference for maintaining their current status or situation even when it may be optimal to actively switch to a different option (Kim & Kankanhalli, 2009). A series of decision-making experiments show that individuals disproportionately stick with the status quo option (Samuelson & Zeckhauser, 1988). The presence of uncertainty between two options is one reason a consumer might maintain the status quo.

C. Energy justice and equity

The identified barriers to solar PV energy access are an issue of energy justice and equity. Typically, more affluent customers are best able to utilize the ITC credits and other financial incentives to invest in rooftop solar, which creates energy injustice. For a tax credit to have a value, the individual or business must owe taxes. Therefore, those who are tax-exempt, or lack sufficient income cannot qualify for tax credits (NREL, 2011). Moreover, the federal residential tax credit requires the PV system installation to be on a home that is owned by the taxpayer and used as the taxpayers residence (NREL, 2011). These financing schemes for solar PV are being critiqued for the inherent imbalance of solar PV distribution and who receives the costs and benefits of solar PV. Augustine & McGavisk (2016) argue that regulators need to reexamine renewable energy policies to ensure fair and equitable treatment of the benefits and costs of solar PV. Financing of new energy infrastructure is in part paid by all utility customers through an approved tariff structure. Therefore, as some utility customers adopt rooftop solar PV and become energy producers, the price the utility pays for excess energy production by rooftop solar customers is subsidized by all other ratepayers without access to solar PV (Welton & Eisen, 2018). Energy justice is an emerging area of study with two main ways in which it has been conceptualized.

McCauley (2013) proposed three key tenets to operationalize energy justice as an analytical tool to evaluate RE developments (see Fig 1).

Figure 1: Energy Justice Tenets



Adapted from Finley-Brook & Holloman (2016)

The second way energy justice has been observed is through eight core principles in the energy decision-making process: availability, affordability, due process, transparency and accountability, sustainability, intragenerational equity, intergenerational equity, and responsibility (Sovacool et al., 2016). The eight core principles create a philosophical grounding for the three proposed tenets by McCauley (2013). The principles create a mechanism by which energy decisions can be more just and equitable in their societal outcomes (Sovacool et al., 2016).

The concept of energy justice as defined by Sovacool et al. (2017) is an energy system that fairy distributes costs and benefits of energy services and has a representative energy decision-making process. The conceptual framework of energy justice addresses the unequal distribution of burdens from decisions made on infrastructure siting, subsidies, pricing, and consumption indicators (Finley-Brook & Holloman, 2016). Therefore, energy justice is used to examine distribution of access to modern energy systems and services as well as ensuring energy decision-making is a representative process (Sovacool et al, 2017). Recent energy policies that target sustainable energy transition are placing a greater focus on principles of energy justice and who pays for the energy transition (Welton & Eisen, 2018). Energy justice is conceptualized into three tenets: (1) distributive justice, (2) procedural justice, and (3) recognition justice. Procedural justice is concerned with the process of who gets to decide and set rules and laws, and which parties and interests are recognized in decision-making. It also examines how impartial or fair are the institutions, instruments, and objectives involved (Sovavool et al., 2016). Recognition justice focuses on cultural and political representation of groups with social, ethnic, and gender differences (LaBelle, 2017). Distributive justice recognizes the unequal allocation of benefits and ills such as siting of infrastructure and access to energy services (Jenkins et al., 2016). The allocation of costs and benefits for clean energy sources can be examined through the lens of distributive justice because the tenet focuses on equitable allocation of risks and opportunities (McCauley et al., 2013). Equitable distribution of energy resources can also be defined as an issue of access to resources and programs (Ribot & Peluso, 2003). "The ability to benefit from resources is mediated by constraints established by the political-economic frames within which access to resources is sought" (Ribot & Peluso, 2003). Based on this definition, access to solar PV is defined as having the opportunity to benefit from the RE incentives and programs that support growth of the solar PV market. The energy equity dimension is commonly defined in terms of accessibility and affordability (World Energy Council, 2015; Forman et al., 2017).

D. Policy tools to expand solar PV access

Governing jurisdictions are recognizing the inherent imbalances in who has access to renewable energy. The previously discussed barriers have spurred policy innovations to overcome issues of access and equity within the renewable energy market.

i. Third-party ownership

A more recent policy tool to diminish financial and technical barriers to solar PV is through third-party ownership (TPO). TPO is a relatively recent market innovation that allows third-party PV companies to own and operate customer-cited PV systems (Drury et al., 2012). The company that owns the PV system will either lease the PV equipment or sell the produced electricity to the building occupant (Drury et al., 2012). Third-party companies can repackage solar PV costs and benefits into simpler terms that show electricity bill savings in the first month of ownership, rather than lengthy payback times or annualized investment returns (Drury et al., 2012). The TPO model eliminates some of the financial barriers such as high up-front costs for residential customers. One drawback of TPO financing for many residential customers is the credit score check. Third-party PV customers are often required to have strong credit scores, which automatically precludes approximately 47 percent of U.S. households from participating in TPO PV systems (Drury et al., 2012).

ii. Community choice aggregation

Community-choice aggregation has emerged as a new model for energy procurement that allows local governments to form an entity that sells electricity to residences and businesses in their jurisdiction. This entity chooses its own power supply portfolio and sets rates (Asmus, 2008). Through CCA, local governments control electricity portfolios while investor-owned utilities are responsible for transmission and distribution (O'Shaughnessy et al., 2019). When a local government establishes a CCA model, it becomes the default provider that automatically enrolls all residents and residents must actively opt-out to remain with their utility service provider (O'Shaughnessy et al., 2019). Currently, eight states have adopted CCA legislation that allows local governments to procure their electricity. CCAs have the potential to be used by local governments as a tool to achieve renewable energy goals. O'Shaughnessy et al., (2019) examined current and future impacts of CCAs on renewable energy demand. The authors concluded that CCAs have a significant impact on voluntary renewable energy demand and consists of more customers than other voluntary renewable energy programs such green blocks provided by utilities. The main advantages of CCAs is giving customers greater access to renewable energy, local control of decisionmaking, and potentially costs savings (Gunther and Bernell, 2019). CCAs are predicted to witness significant growth as more states are considering legislation. However, solar PV has not played a significant role in CCA sales, with wind accounting for 78 percent of all renewable energy sales (O'Shaughnessy et al., 2019).

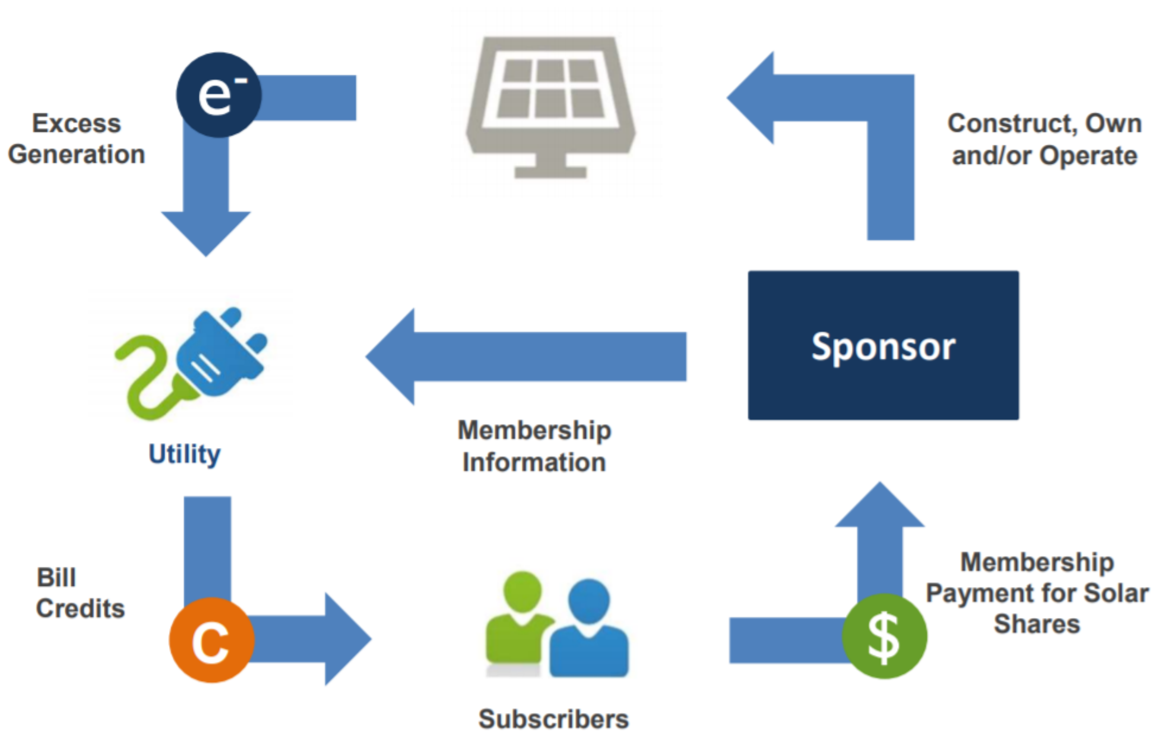
iii. Community renewable energy: solar PV

The term community energy is increasingly used in sustainable energy literature to denote renewable energy projects that are local, small-scale, and usually collectively funded (Peters et al., 2018 & Walker et al., 2007). However, there is no universal definition of community energy. Community can refer to place, practice, or interest (Peters et al., 2018). Community renewable energy (CRE) projects can be 100 percent community-owned or they can be developed with private sector co-ownership (Walker, 2008). The energy produced by the project can be locally produced and consumed or the project can be interconnected and fed into the grid (Walker, 2008). The effort to build CRE projects was pioneered by municipal and cooperative utilities with little initial support from government resources (Augustine & McGavisk, 2016).

In recent years, community solar (also called shared solar, solar farms, or community distributed generation) has gained prominence as a policy tool to overcome barriers to solar PV access. Community solar allows for multiple utility customers to purchase or lease a portion of a solar array facility that is not located on their property, and to have the electricity produced by their share of the system offset the electricity consumption of their home or business (DSIRE, 2019). To date, 15 states and Washington DC have passed community solar legislation, with Illinois, New Jersey, and Oregon being the most recent states that are still in the process of program implementation (Chan et al., 2017; Interstate Renewable Energy Council, 2019). The earliest adopters of mandated community solar programs are Minnesota, Colorado New York, and Massachusetts, and therefore, these states have the most established community solar programs. Community solar enables a wider range of utility customers to participate in the solar market, which can include renters, apartment/condo residents, multifamily building residents, homes and business with ill-suited roofs, and those who do not have the capital to invest in rooftop solar ownership. Community solar model expands availability of distributed solar PV generation to more customers, offers economies of scale for project development, and can address the issue of solar PV subsidization across utility ratepayers (McLaren, 2014). The policy can also be used as a tool to give solar PV access to low-income customers and marginalized communities, who often rent, have lower credit scores, and limited funds (Cook & Bird, 2018). Energy policy research has also suggested that community solar has the potential to address distributive justice and equity concerns in solar PV market (Cook & Bird, 2018; Hoffman & High-Pippert, 2015). Traditionally, community solar was based on customer ownership model, where either an electric retail utility or a nonprofit organization coordinated the funding, installation, and maintenance efforts but the utility customers paid an upfront onetime fee to offset system costs. However, recent state mandated community solar policies focus on a newer and more affordable model that is based on customer subscriptions, where a utility ratepayer voluntarily subscribes to a community solar project and receives a utility bill credit each month for their portion of community solar energy production (see Fig 2). In policy discourse, community solar refers to a form of distributed generation that involves a solar array facility and group subscriptions by customers of all classes: residential, commercial, government, or industrial retail customers. These subscribers are located within close proximity of each other, and receive a portion of the total production energy capacity in the form of credits on their electric bill (Colorado Energy Department, 2018). Community solar participants can receive credits for the electricity generated from a shared solar project in various ways. In states with community solar legislation, customers typically receive a one-to-one credit for each kilowatt-hour the solar system generates. Virtual net-metering is a variant of net-metering and allows for off-site project participants to receive credits that are distributed among multiple subscribers. In addition to virtual-net metering, bill credits can also be allocated based on a predetermined value of solar rate or tariff (NREL, 2015).

Community solar policy can structure the programs to be either owned and operated by the utilities or by private third-party providers. The policy landscape dictates state specific community solar program structure, which has resulted in diverse program rules and program implementation and operations across states. Program design rules are typically driven by policy goals. The policy can determine who is allowed to utilize the established program incentives, which determines who participates in the program. Utilities, businesses, local governments, and community groups can host community solar projects. These systems can be located on public buildings, private land, brownfield sites, or any other location with suitable solar resources (McLaren, 2014). Program design elements include total program size cap, project maximum capacity, minimum and maximum subscribers, eligibility rules, incentive payout rules, bill credit rules, location requirements, and included utilities (Stanton & Kline, n.d.). Once a program structure has been established, the system developer finds investors and eligible utility to site the project and establish interconnection (Augustine & McGavisk, 2016). The system developer can own and operate the project and manage subscribers or sell the project as an LLC. Another important element of community solar are the contract agreements between project owners and subscribers, which are not regulated (Chang et al., 2017).

Figure 2: Community Solar Participants and Structure



iv. Community solar policy objective: expanding solar PV access

Various organizations, advocacy groups, and state governments present community solar as a tool to expand solar PV access to residential, especially low-income customers. The Coalition of Community Solar Access is a national partnership of businesses and nonprofits working to expand solar access through community solar. The coalition promotes community solar as a way to "provide homeowners, renters, and businesses equal access to the economic and environmental benefits of solar energy generation". The organization states that community solar is a tool to expand "access for all", which includes low-to-moderate income customers (Coalition for Community Solar Access, 2018). The push to expand solar PV access to residential and low-income customers is noteworthy because developers had previously pursued large electricity users and wealthier households who "pose a lower risk of attrition" (Chan et al., 2017). A group of nonprofit organizations published the "Low-Income Solar Policy Guide" that advocates for community solar as a tool to "expand access to a broader group of energy consumers than the current solar policies allow" (Browning et al., n.d.). The published guide provides a list of barriers to solar PV access for low-income consumers and ways that community solar programs can address them. The National Renewable Energy Laboratory has also published extensive reports on community solar programs, which includes a review of current low-income community solar programs (Feldman et al., 2015; Cook & Shah, 2018; Heeter et al., 2018; Cook & Bird, 2018). U.S. Department of Energy SunShot Initiative published a guide for policymakers that provides recommendations for policies that aim to expand solar PV access for low-income consumers (Coughlin et al., 2011). The guide has a heavy focus on community solar as tool to enable a wider range of customers including residential and low-income to participate in the solar PV market. Expanding solar PV access is now part of state political agendas, and community solar programs are being used as a policy tool to address the objective of expanding access to a broader retail customer base. Table 3 demonstrates the objective of expanding access for the four community solar programs examined in this study.

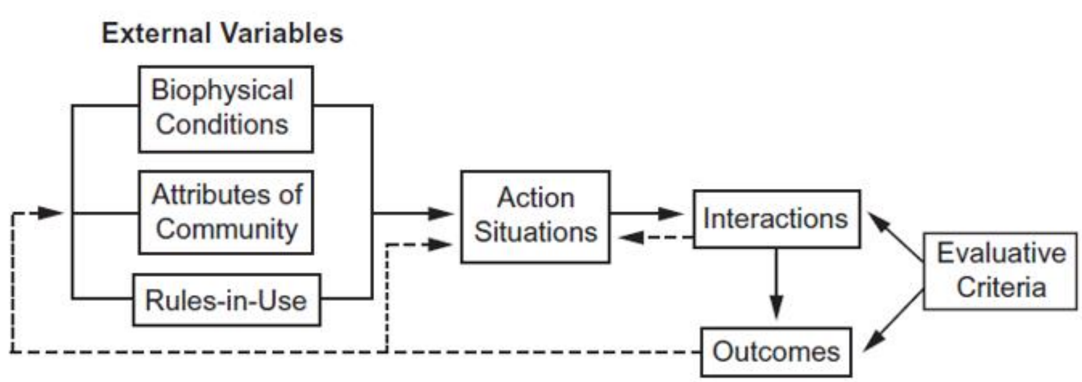
Table 3: Expanding Solar PV Access as a Policy Objective of Community Solar Programs

State:	Policy/statute language:	Source:
MN	"Expanding access to the benefits of solar to customers who are traditionally unsuited to rooftop solar . . . , [including] customers who lack access to an appropriate roof location, are unable to afford the upfront costs of an installation, or are discouraged by system maintenance or other considerations." "One aspect of the bill was aimed at the problem that not all homes and businesses can or want to put solar panels on their roof or property"	Minnesota House of Representatives Information Brief on "Xcel Energy's Community Solar Garden Program" Institute for Local Self-Reliance and MnSEIA
CO	"Provide Colorado residents and commercial entities with the opportunity to participate in solar generation" "Allow renters, low-income utility customers, and agricultural producers to own interests in solar generation facilities"	House Bill 10-1342 (2010)
NY	"Initiative is directed towards unlocking access to solar generation for those households and business otherwise unable to participate"	New York Public Service Commission Order15-E-0082
MA	"Address financing barriers limiting residential and non-profit direct ownership, without compromising third-party ownership mode" "The purpose of 225 CMR 20.00 is to establish a statewide solar incentive program to encourage the continued use and development of generating units that use solar photovoltaic technology by residential, commercial, governmental and industrial electricity customers throughout the Commonwealth"	Massachusetts Department of Energy Resources SREC II Program Massachusetts Department of Energy Resources SMART Program

III. Institutional Analysis and Development Framework

To understand and analyze the institutional arrangements of community solar programs, this study will operationalize Elinor Ostrom's Institutional Analysis and Development (IAD) framework. Past applications of the IAD framework in energy policy research have focused on wind energy cooperatives, water-energy-food nexus, smart grids, energy crises policy, and electricity access (Amin & Bernell, 2018; Lammers & Heldeweg, 2016; Pasteris, et al., 2005; Schipper, 2014; Villamayor-Tomas, et al., 2015; Lammers & Hoppe, 2019). The IAD framework is a conceptual map (see Figure 3) used to study and understand how actors' behavior is guided and constrained by institutions and how human behavior shapes and changes institutions over time (McGinnis, 2011; Schlager & Cox, 2018). One of the values of the IAD is that it supports comparative institutional analysis by providing a set of concepts, variables, and evaluative criteria for systematic comparison (Schlager & Cox, 2018).

Figure 3: A Framework for Institutional Analysis



Adapted from E. Ostrom (2010)

Ostrom (2011) makes a distinction between a theory, model, and framework where the latter provides a general list of variables that are used to analyze institutional arrangements. Traditionally, institutions are thought of as physical organizations, but Ostrom (2010) defines institutions as the rules used to define interactions between involved actors. Therefore, the framework conceptualizes institutions as rules, norms, and strategies used by stakeholders operating within or across organizations (Ostrom, 2010).The purpose of the IAD is to examine patterns of interaction, outcomes, and an evaluation of those outcomes (Ostrom & Cox, 2010). The framework provides a set of variables used to map situations where players are constrained by events, governing rules, and the physical environment (Ostrom & Cox, 2010). The framework offers a diagnostic approach to analyze various aspects of policy processes where institutional choices are implemented (Heikkila & Andersson, 2018). Gaining an understanding into the how and why of institutional design enables development of informed proposals to improve institutional performance. The IAD incorporates multiple levels of analysis to examine the role of rules at operational level, policy level, and constitutional level.

Ostrom defines the type of activities that occur at each level. Constitutional level identifies who participates in the rulemaking process, which determines the rules at the policy level and their application at the operational level (Sabatier & Weible, 2017). Rules at each level of analysis are nested in another and therefore a change in one set of rules will lead to rule alterations at other levels. This paper analyzes actor interactions at the operational level where production, distribution, and consumption occur and the outcomes of these interactions in light of the rules that constrain their behaivor.

The central unit of analysis in the IAD conceptual map is the action situation, which is depicted in Figure 3. The action situation is used to "explain, predict, and analyze behavior in institutional settings" (Ostrom, 2011). Therefore, the first step is to identify the conceptual unit or the action situation central to the level of analysis at interest. An action situation can be conceptualized by clustering any of the seven variables defined by Ostrom (2011): (1) participants, (2) positions, (3) outcomes, (4) action-outcome linkages, (5) allowable actions, (6) information, (7) costs and benefits of outcomes. Action situations depict a social space where actors interact, exchange goods and services, solve problems, dominate one another, etc. (Ostrom, 2010). The action situation identifies patterns of interactions and outcomes, and an evaluation of these outcomes (Ostrom, 2011). The actions, interactions, and outcomes of an action situation are structured by institutions or rules that determines the who, what, or how of the action situation (Heikkila & Andersson, 2018). Therefore, the rules that governor actions are also a central component to the IAD framework.

Rules shape the action situation and are often used as the main variable to describe patterns of interaction and outcomes. These rules can include the "rules in use", which are the working rules or the "rules in form", which are the written laws. Rules are the blocks that support cooperation among actors and allow for coordination of actions and outcomes that cannot be achieved independently (Sabatier & Weible, 2017). In this paper, the "rules in form" is the central variable of analysis that determines institutional design of community solar programs.

Action situations can be studied in context of other external variables: biophysical conditions and community attributers. Community attributes can include characteristics such as socioeconomic status, community culture, and levels of social capital. Biophysical conditions are defined as: (1) cost of excluding individuals from a good, (2) subtractability of resource flow, and (3) mobility of resources (Ostrom & Ostrom, 1999). The IAD framework has been used by scholars to study common pool resources and public goods, which are characterized by subtractability or what one actor consumes is not available for others (Heikkila & Andersson, 2018). Attributes of community refers norms and cultures of the actors examined in the action situation (Ostrom, 2009). Biophysical conditions and community attributes are most commonly used in research that focuses on common pool resources and are less relevant for the study of community solar programs.

The IAD framework provides an analytical structure to examine the effects of the written community solar rules on the action situation, interactions, and outcomes. The repeated interactions between actors creates a pattern of interaction that can be studied based on a chosen evaluative criteria. Evaluation criteria of the institutional arrangements, processes, and outcomes of action situations are similar to those used in other forms of public policy analyses (Stone, 2012; Sabatier & Weible, 2017). The evaluation criteria can include effectiveness, efficiency, equity, and accountability (Sabatier & Weible, 2017). For this study, the evaluative criteria is based on residential and low-income access to community solar programs.

IV. Methods

For the institutional analysis of community solar programs and to examine residential and low-income access, four state programs were selected: Minnesota, Colorado, New York, and Massachusetts. These four community solar programs were selected based on the criteria of 1) being a state mandated program, 2) main program goal is to expand access to residential and low-income customers, 3) earliest program adopters with most operational experience, and 4) substantial program growth. This study employed qualitative methods involving the collection and analysis of secondary data including relevant documents, along with primary data obtained from semi-structured interviews with key stakeholders. The work proceeded in three stages. First, a review of the publicly available information – including news articles, reports, and policies – was conducted to gain a general sense of the important elements of community solar program design. The information accessed included: 1) government statutes, rules, and dockets, 2) industry reports, 3) trade journal articles 4) press releases from legislative offices, environmental groups, and investor owned utilities. This included reports from National Renewable Energy Laboratory, U.S. Department of Energy Sunshot, Minnesota Department of Commerce, New York State Energy Research and Development Authority, Colorado Energy Office, and Xcel Energy. The rules and regulations came from Minnesota Public Utilities Commission, Minnesota Legislature, New York Department of Public Service, Colorado Public Utilities, Colorado House of Representatives, and Massachusetts Department of Energy Resources. Trade journal articles came from Utility Dive, Energy Sage, Community Solar Hub, GW Solar Institute, Solar Power World, Greentech Media, PV Magazine, and Clean Energy Authroity.

In the second stage, individuals were interviewed. These interviews represented the most significant part of the research, and provided a rich and firsthand source of information about the institutional design of community solar programs. The technique for choosing interview subjects involved purposive sampling, in which interview subjects were selected based on their involvement and knowledge of community solar programs in the four states: Minnesota, Colorado, New York, and Massachusetts. Interviewees were identified based on the NREL's Community Solar Project Database, which is the most comprehensive list of community solar projects in the U.S. by state and associated utility. Based on this information, online public records provided contact information for relevant individuals involved with community solar programs in the four selected states. This included requesting interviews with utilities, state agencies such as the Public Utilities Commission and Energy Office, community solar project developers and administrators, and nonprofits also known as Solar Community Organizations (identified based on Appendix in Noll et al., 2014). that advocate for community solar projects. Additional interview subjects were identified using snowball sampling, a technique where each interviewee is "asked to suggest additional people for interviewing" (Babbie, 2007). All interviewees were approached in their professional capacity as it relates to their work with community solar programs. A total of 75 individuals were contacted with an interview request, resulting in 16 interviews. These individuals were affiliated with regulatory agencies, utilities, solar developers, and solar nonprofit organizations. Table 2 provides a list of the number of interview respondents from each stakeholder group.

Table 1: Interview Respondents by Stakeholder Group

	# of Respondents
Government agency	4
Investor-owned utility	3
Project develop/owner	6
Solar community organization	3
TOTAL	**16**

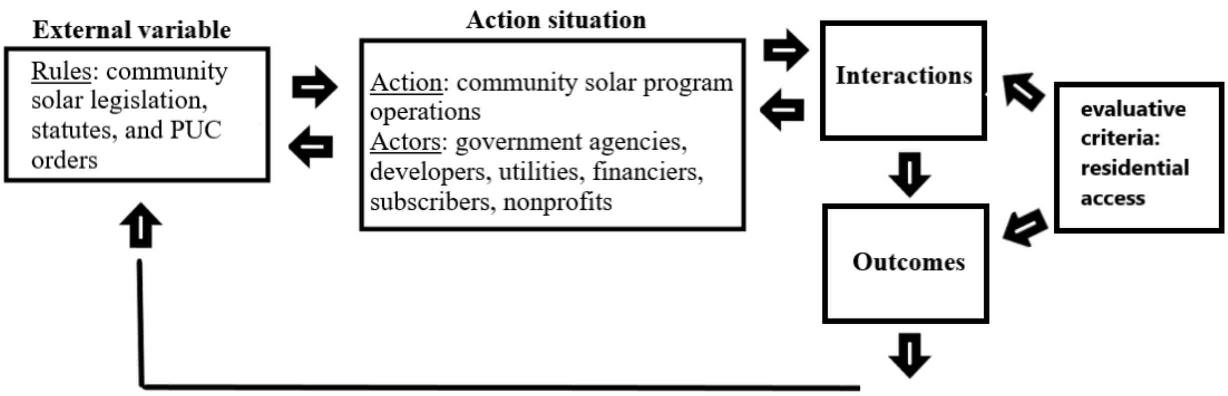
Some interview respondents requested for their affiliated organizations to remain anonymous. However, when respondents granted permission for their names to be used, quotes have been attributed to these individuals. All citations of interviews include the individual's sector, which are noted as government (GOV), the private sector (PVT), or non-governmental organizations (NGO). The questions put to the respondents had to do with community solar program regulations, design, and outcomes. The main questions asked about: 1) program goals, 2) the role of the organization, 3) program rules, 4) program incentives, 5) program costs and benefits, 6) program subscribers, 7) program challenges and, 8) desired program improvements. These semi-structured interviews were conducted via telephone and lasted from 30 to 60 minutes. In the third stage of the research, audio recordings from the interviews were transcribed and analyzed. Interviews were transcribed using Trint software with manual edits. The edited interview transcripts were then imported into Dedoose, a web-based application for analyzing qualitative and mixed-methods data. Coding and analysis were conducted via this platform, and emergent themes based on the IAD framework were identified. This study used both inductive and deductive coding approach. The initial codebook was developed based on variables identified by the IAD framework and later modified to include additional codes based on interview trends. Passages were marked with a code when they depicted a relevant variable or theme.

V. Analysis

For this study, the IAD framework provides a conceptual map by which to organize and analyze research findings. This study examines the written community solar rules and how they impact the action situation, which consists of program stakeholders and community solar program operations. The rules determine community solar program configuration for the four states examined in this study. The institutional design of community solar programs results in unique interactions and outcomes when the actors are given the written rules and tasked with program operations. This provides an opportunity to examine these interactions and outcomes and link them back to program design. The outcomes are based on predetermined evaluative criteria of expanding solar access to residential and low-income customers. This study uses an adapted version of the IAD framework, which does not examine biophysical conditions and community attributes because they are not as relevant to the institutional design of community solar programs.

The analysis section is structured as follows: The first section outlines the written community solar rules for Minnesota, Colorado, New York, and Massachusetts based on state policies and regulations. The rules section includes community solar market statistics for each state and contextual information for each state community solar program. Next section gives an overview of the program actors and their roles in community solar program operations. This is followed by a discussion of the interactions that occur based on each program design. The last section considers the interactions for the four programs and presents program outcomes based residential and low-income customer access. The adapted IAD framework for this study is presented in Figure 4.

Figure 4: Institutional Analysis of Community Solar Programs



Adapted from E. Ostrom (2010)

A. Rules

Community solar rules governing program operations are defined in statutes either by the executive branch, the state legislature, or the state utility commission. The state utility commission approves details of program operation and regulates program implementation. Because electricity markets are regulated on a state-by-state level, the actual design and operations of programs can vary and are filled with nuances when it comes to program requirements, incentives, financing, and other aspects. The origin of each policy differs, from meeting mandated RPS standards to encouraging state solar development. The next section will outline community solar rule attributes for the four state programs examined in this study. Table 3 shows the size of the community solar markets in Minnesota, Colorado, New York, and Massachusetts in relation to the state's overall solar market.

Table 2: Current Solar Market Statistics

State	Total installed solar capacity	Total installed community solar capacity	% community solar	% total state electricity from solar
MN	1,206 MW	559 MW across 216 projects installed 381 MW pipeline	46%	2.49%
CO	1,268 MW	56 MW across 28 projects installed	.04%	3%
NY	1,775 MW	40 MW across 20 projects installed 800 MW pipeline	.02%	1.62%
MA	2,567 MW	600 MW installed 600 MW pipeline	23%	11.81%

Source: SEIA (2019)

The next section provides an overview of community solar program growth for the four state programs. The background information contextualizes each state program and assists in interrupting the findings of this study.

Minnesota

Minnesota passed community solar legislation as part of the 2013 Solar Energy Jobs Act (HF 729). The Minnesota legislature ordered the state's largest regulated utility, Xcel Energy, to develop and implement the community solar program based on the guidelines provided by the legislature (Chan et al., 2017). Xcel Energy proposed an incentive program for community solar called the Solar*Rewards Community program, which was approved by the Public Utilities Commission in 2014 (Chang et al., 2017; Xcel Energy). Within the first month of community solar program operation, Xcel Energy received applications for 431 MW of solar development. By 2015 the development applications increased to 1,000 MW (Chang et al., 2017). In 2013, Minnesota passed new legislation that presented an alternative to net-metering called value of solar (VOS). The 2013 legislation mandated that the VOS accounts for the value of energy and its delivery, generation capacity, transmission capacity, transmission, and distribution line losses, and environmental value (Chang et al., 2017). The legislation also mandated that solar customers are billed for their gross electricity consumption under their applicable tariff and receive a VOS credit for their gross solar electricity production (Chang et al., 2017).

Colorado

The Colorado legislature passed House Bill 1342 in 2010 called the Community Solar Gardens Act, it mandated a five percent low-income carveout for all community solar projects built under the program. The bill tasked Colorado's largest IOUs, Xcel Energy and Black Hills Energy, with the development of a proposal for the acquisition of the renewable energy from the community solar program (Colorado House of Representatives, 2010). Xcel Energy, which serves approximately half of Colorado's residents, established the Solar*Rewards Community program. Under the program, Xcel Energy purchases the energy and renewable energy credits (RECs) generated from qualified solar projects (Xcel Energy, 2019). Both Xcel Energy and Black Hills Energy issue an RFP soliciting project development bids from solar developers. The developer bids must include: a REC incentive price, the system location, a summary of the developers experience, a financing plan, and project development plan. The Public Utilities Commission determines the annual energy Xcel must acquire from the community solar program. In 2014, PUC set the target between 19.5 MW to 90 MW by the end of 2016. Xcel Energy solicited RFP bids through 2018 for up to 37 MW of community solar (Xcel Energy, 2019). In 2019, the Coloreado legislature expanded community solar gardens in HB 19-1003: Community Solar Gardens Modernization Act, which increased project capacity from 2 MW to 5 MW.

New York

The community solar program in New York is a part of the state's NY-Sun Initiative. This initiative seeks to reduce the cost of solar electricity systems and sets aggressive targets for solar deployment in New York. It provides long-term funding through a one-billion-dollar commitment over ten years to support solar projects (NYSERDA, 2019). New York's community solar program is also part of New York's Clean Energy Standard, which has set a target of 70 percent of New York's electricity to come from renewable energy sources by 2030 (NYSERDA, 2019).

The New York State community solar program aims to support the Reforming the Energy Vision (REV) initiative, which is seeking to reform the state's energy industry and regulatory practices (NYSERDA, 2019). In addition to REV, New York community solar also aims to further the objectives of the New York Clean Energy Fund (CEF), striving to achieve self-sustaining clean energy industries in New York. New York community solar has received $13.5 million in funding from 2014 to 2023 through the NY-Sun initiative, with $10 million budgeted for the first five years of the community solar program operations (NYSERDA, 2019). The NY-Sun initiative funding comes from The New York State Energy Research and Development Authority (NYSERDA), the Long Island Power Authority (LIPA), PSEG Long Island, and the New York Power Authority (NYPA). NYSERDA manages the NY-Sun Initiative that supports state community solar programs. As part of that funding, NYSERDA also administers a low-income subset of community solar called Solar for All. Solar for All is designed to provide cost-free community solar to 10,000 low-income homeowners and renters in support of the state's ongoing efforts to make renewable energy more accessible to all New Yorkers. Solar For All offers eligible low-income households the opportunity to subscribe to a community solar project in their area without any upfront costs or participation fees (NYSERDA, 2019).

Massachusetts

In 2007 Massachusetts only had 3 MW of solar generation, which prompted Governor Patrick to establish a solar goal for Massachusetts of 250 MW by 2017. The following year, Massachusetts Senate passed SB 2768, the Green Communities Act, which established virtual net-metering that allowed the transfer of electricity credits for full retail value. The solar goal and expansion of net-metering set the stage for solar growth in the state. However, the policy limited the amount of solar that was eligible for net-metering. The Green Communities Act tasked the Massachusetts Department of Energy Resources (DOER) with developing a solar carve-out (a minimum level of solar power) for the Renewable Portfolio Standard (RPS). DOER was tasked with determining eligible technologies, minimum standards, and an alternative compliance payment (ACP) rate for the carve-out (DOER, 2019). The DOER used the state RPS standards to expand the solar market by creating solar renewable energy certificates (SRECs), which establish a value for the environmental and societal benefits for solar power generation. SRECs were combined with compensation for solar energy through net-metering. The first program was SREC-I that operated from 2010 to 2014, and met the goal of 250 MW of solar development four years ahead of schedule. The rapid solar boom prompted Massachusetts to set a much higher solar goal of 1,600 MW by 2020. In 2014, DOER expanded the solar carve-out by establishing SREC-II. The SREC-II program met it's solar development goal of 1,600 MW by 2018. The SREC prices for both programs were determined by five factors: the SREC program design, supply, demand, the Solar Alternative Compliance Payment (SACP), and the Solar Credit Clearinghouse Auction (SCCA). SACP is the penalty that electricity companies pay if they fail to meet the required number of SRECs by the end of each compliance period (DOER, 2019). This price decreases over time in both programs. SCCA stabilizes the price of SCRECs by setting a predetermined price. SCCA rules did not force the utilities to purchase SRECs through SCCA, but simply offers another option to comply with RPS standards and avoid penalties (DOER, 2019). In 2016 new legislation directed the DOER to develop a successor to SREC-II that would create a sustainable long-term incentive program to promote cost-effective solar development (Vote Solar, 2019). The legislation increased net-metering caps to allow for larger community solar development. DOER worked with state investor-owned utilities to develop the Solar Massachusetts Renewable Target (SMART) program with the goal of expanding solar capacity by additional 1,600 MW of generation with declining incentive blocks. The SMART program was officially launched by end of 2018 and is already close to reaching the 1,600 MW development goal (DOER, 2019).

i. Program requirements

Community solar laws and regulations create project parameters by which all eligible participants must comply. The majority of community solar programs place an annual program cap established by the state PUC. Another typical project constraint is set by the maximum allowed output from a single community solar project. As the state community solar programs grow in size, states tend to continue to increase the maximum output capacity for a single solar project. Three out of the four states examined are now at 5 MW maximum capacity per project. Table 4 presents a state comparison of the program design rules. The most notable rule is Minnesota not setting an annual program cap.

Table 3: Community solar program requirements

State	**Law**	**Program size cap:**	**Project max capacity**[1]
MN 2013	Solar Energy Jobs Act (HF 729) MS 216B.1641 (revision)	No cap	*2013*: 1 MW *2015*: 5 MW
CO 2010	*2010*: HB 10-1342 *2019*: HB 19-1003	Annual capacity established by the PUC	*2010*: 2 MW *2019*: 5MW
NY 2015	NY-Sun Initiative PUC order: 15-E-0082	Annual capacity established for each IOU by the PUC[2]	*2015*: 2 MW *2019*: 5MW
MA 2008	Solar Carve-Out Program as part of Green Communities Act[3]	Annual capacity established by MA DOER with a target of 1,600 MW by 2020	2-5 MW[4]

[1] Minnesota's program also includes a minimum subscription amount of 200 watts
[2] Based on the allocated value stack for each utility
[3] DPU adopted rules implementing new net metering law that enabled neighborhood net metering and increased the eligible system size to 2 MW
[4] According to MA DOER, projects using net-metering are capped at 2MW and projects using alternative on-bill crediting are capped at 5 MW

ii. Eligibility and participation rules

Community solar legislation can designate the role of the program administrator to either a retail utility, state government agency, or a third-party. As a result, states have taken different approaches to who is tasked with program administration. Policies also specify which utilities must comply with the community solar rules and the utilities might also tasked with various responsibilities such as producing interconnection rules for project developers. The program rules also set a minimum and maximum number of subscribers for a single solar project as a way to achieve the desired balance between large and small customers (residential, business, commercial, industrial, etc). Project participation eligibility is dependent on subscriber's location and the proximity of a given community solar project. Table 5 below presents a comparison of state community solar eligibility and participation rules.

Table 4: Community solar project eligibility and participation rules

State	Program administrator	Included utilities	Location requirement	Min/Max subscribers	Subscriber restrictions	Low-income provision
MN 2013	Xcel Energy (largest IOU)	Xcel Energy	Within the same county or contiguous county	5, 120[5]	Yes[6]	None
CO 2010	Xcel Energy (largest IOU)	IOUs	Within the service territory of the same utility[7]	10,120	Yes[8]	5% of project subscriptions have to be low-income
NY 2015	New York State Energy Research & Development Authority (NYSERDA)	IOUs	Utility service territory, with development zones identified by utility	10, 100[1]	Yes[9]	NYSERDA Solar for All Program
MA 2008	Department of Energy Resources (DOER)	IOUs	Within the same ISO load zone as its customers, and its customers must be served by the same utility	10-no cap	Yes[10]	Housing Authorities authorized to participate (incentive adder discussed later)

[5] A single subscriber can't have more than 40 percent share of a project or sign up for greater than 120 percent of their average electricity use

[6] Single subscription must not exceed 40% of a single community solar project capacity

[7] Regulation changed in 2019 from 2015 regulation requiring within the same utility and in the same county or adjacent country of community solar project

[8] A single subscriber may not apply for more than 40 percent of a garden's allocation using multiple premises, debtor numbers or metered locations

[9] No more than 40% of the generation may serve large demand-metered (25 kW or greater) subscribers. The remaining 60% of the generation must be allocated to subscribers at 25kW or less

[10] Net-metering on bill-credits allow 1-2 subscribers that are 25 kW or greater & no more than 50% of project energy capacity

Minnesota

In Minnesota, the community solar policy delegates the responsibility of administering the program to the state's largest investor-owned utility, Xcel Energy. The utility is also required to administer the incentives program in the form of payments for the energy acquisition from all interconnected community solar projects. Xcel Energy services 1.2 million customers out of the 5.6 million in the state of Minnesota. The rest of the residents are served by cooperatives and municipalities which account for 170 out of 174 electric utilities. Xcel Energy is the largest regulated utility in the state and therefore the only IOU that's mandated to host a community solar program. The eligibility rules require that the project subscribers are located within the same country or contiguous county as the community solar project. Any potential community solar subscriber that is not serviced by Xcel, cannot participate in the community solar projects that are interconnected with Xcel Energy. The policy has set the minimum and maximum limit of subscribers for a single project between 5-120 subscribers. Community solar rules in Minnesota do not have provisions for the type of subscribers that are eligible to participate in the program and there is also no low-income carveout. The program rules prevent a single subscriber from taking 40 percent or more of the energy capacity. The policy allows any entity to develop community solar, which includes the IOUs.

Colorado

In Colorado, the responsibility of program administration was given to the state's largest utilities, Xcel Energy and Black Hills Energy. The utilities developed separate plans for project approval and interconnection based on an RFP process, which was approved by the Colorado PUC. The IOUs are also responsible for managing subscribers' net-metering in the form of on-bill credits.

Colorado has two eligible community solar utilities, Xcel Energy and Black Hills Energy. Xcel Energy is much larger and services 1.2 million Colorado residents out of 7 million residents, while Black Hills Energy serves under 100,000 customers. Xcel's program much larger (40 MW vs 2.5 MW), therefore this study only focuses on Xcel's program. The rest of Colorado residents are served by the 29 municipal utilities and 22 rural electric cooperatives . The community solar project subscribers must be serviced by the same utility as the community solar project they are subscribed to. Colorado policy states that the number of subscribers must be between 10-120 per community solar project. Colorado community solar policy has a low-income provision in place for project developers to include a minimum of five percent low-income subscribers per project. The program rules say that a single subscriber may not apply for more than 40 percent of a project's allocation using multiple premises, debtor numbers or metered locations. The policy allows any entity to develop community solar projects, including IOUs.

New York

The responsibility of administering the community solar program in New York is undertaken by the New York State Energy Research and Development Authority (NYSERDA). The agency also manages a low-income community solar program called Solar for All. Solar developers can choose to participate in the RFP process for this program by allocating a percentage of their project's solar capacity to low-income, which would be paid for and managed by NYSERDA. The program rules also allow for housing authorities to participate on behalf of low-income subscribers. Community solar subscribers in New York can only participate in projects that their utility provider is interconnected with. A single community solar project must have between 10-100 subscribers. The policy requires at least 60 percent of any project's subscribers to be small or nondemand customers, which is referred to as the 60/40 rule. The program rules in New York do not allow for utilities to develop community solar projects. Only private developers and other third-party organizations such as energy service companies (ESCOs) and nonprofit organizations are allowed to developer under the state mandated program.

Massachusetts

The Massachusetts community solar program is administered by the DOER. The state agency is also responsible for designing and managing the community solar incentives programs, SREC-II and SMART. In Massachusetts, community solar projects must be within the same independent system operator zone as the project subscribers and the subscribers must be served by the same utility to which the project is interconnected. The rules require that projects must have a minimum of 10 subscribers with no upper limit. Massachusetts does not have a low-income subscriber provision, though the program allows for housing authorities to participate on behalf of low-income subscribers. The most recent incentives program, SMART, has also included an additional adder for low-income project subscribers. The policy requires that no more than one or two subscribers receive a net-metering credit greater than an amount equal to 25 kW of the nameplate capacity of the generation unit, and those two subscribers cannot take more than 50 percent of the total. This is a form of participation rule that limits the number of large commercial subscribers per project. Massachusetts does not allow utilities to develop community solar projects. This is done by private, for-profit entities and nonprofit organizations.

iii. Financing and incentives

Community solar programs are established to provide financial incentives to developers and subscribers of community solar projects. Projects rely on these incentives to make project economics work. At the federal level, projects can utilize the ITC to offset system costs. At the state level, each state has developed its own framework of how the costs and financial benefits of community solar are distributed. The main source of incentive funding comes from the purchase of RECs and the renewable energy paid by the state utilities (commonly investor-owned utilities). These price frameworks have evolved over the years and vary across state community solar programs. The subscriber bill discount is derived from the electricity produced by subscriber's share of solar generation and applied as a credit on their utility bill. Therefore, community solar subscribers still use their default electricity mix from the utility and receive bill credits from the utility for their portion of community solar energy generation that is sent to the electric grid.

Virtual net-metering has been the main policy tool used to guarantee subscribers of community solar a discount on their existing utility bills. According to a private community solar developer, "Every developer has their own marketing or financial benefit to the customer. We provide 10 percent savings to the customer. In terms of financing every developer has their own models as well. Any developer/financier/owner/operator has their own financing model" (Interview 3 – PVT). Therefore, the exact mechanism by which the community solar projects are financed is not disclosed. The developers do not openly share this information. The project subscribers enter into a contract agreement with the project owner or operator (which might be the same developer or another private entity that bought the project). These contract agreements vary by program and project but generally might include: subscription length, subscription fees, transfer fees, or termination fees. One of the nonprofit organizations that works on community solar access issues in New York and Massachusetts stated, "The industry standard till very recently was about 20-year commitment for a contract and often a cancellation fee. A lot of states are now requiring a disclosure form that just sits on top of the contract and highlights the guaranteed savings, cancellation fee, and what's inside these articles" (Interview 10 – NGO). Each month the solar production from a community solar garden is recorded in kilowatt hours (kWh). The total kWh production recorded from the community solar project is then allocated based on each individual's subscription. The individual allocations are calculated into a bill credit by multiplying the number of kWh for the subscriber by their credit factor ($/kWh). The difference between the compensation the subscriber receives from their portion of community solar generation minus the community solar subscription fee is the net-benefit the subscriber receives for their participation in the form of bill credits from their utility company. However, the details of these transactions can be complicated and difficult to understand. A representative of the Colorado Energy Office said, "I don't know what transpires between the developer and the customer" (Interview 1 – GOV). However, one private developer gave some insight into what transpires between their company and a community solar subscriber

> [Our financing partners] require that [potential subscribers] pass a credit check. It's a part that we're not really involved with because that goes directly from our financing partner…Typically we require a single month upfront payment. Really what that is a security deposit so they're one month ahead on their billing. We would be finding a cost amount that was relative to their electric usage so everyone would have a different amount.

The monthly payments are the same throughout the year. There are cancellation fees (Interview 11 – PVT).

Table 5: Community solar project incentives and compensation

State	**Incentives/subscriber compensation**	**Adder for residential**	**Adder for low-income**
MN 2013	Solar*Rewards Community Tariff (virtual net-metering) (2013) Value of Solar (VOS)[11] (2018)	$ 0.015	None
CO 2010	Solar*Rewards Community Tariff[12] (virtual net-metering)	None	None
NY 2015	NY-Sun Initiative + Virtual net metering (2015) VDER/Value stack (2017)	None	None
MA 2008	SREC-II + net-metering (2010) SMART[13] tariff + net-metering (2018)	None	$ 0.06[14]

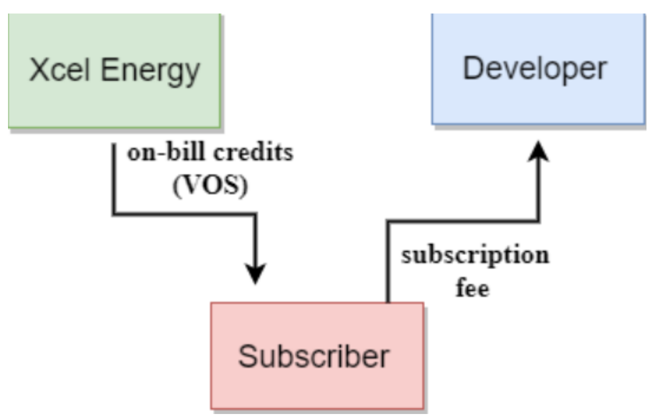
[11] MN Laws 2013, Chapter 85 HF 729, Article 9, Section 10
[12] The net-metering credits are multiplied with the subscriber's share of the community solar output minus accrued costs by the utility for community solar integration, administration of contracts and net-metering credits. Excess generation credit is carried to the next month's consumption and reimbursed by the utility if generation exceeds consumption in a year.
[13] DPU order 17-140-A
[14] This is not on top of the $ 0.05 but instead of. So low-income is only 1 cent more

Minnesota

In Minnesota, the largest state investor-owned utility, Xcel Energy, administers the incentive program called Solar*Rewards Community Program. The program was initially based on the value derived from net-metering, but recently transitioned to value of solar (VOS), under which RECs are given to Xcel Energy for 25 years. The Value of Solar is simply meant to calculate the economic and environmental value of solar to the energy system and to customers and the utility in Minnesota (Interview 6 – NGO). According to the Minnesota Department of Commerce, the VOS tariff Xcel Energy pays is what helps to finance the community solar projects. The Citizens Utility Board of Minnesota described the economic transactions in Minnesota, "The utility is taking the power as a resource and they're paying for the RECs and they're paying for the wholesale price of the power. And then any difference the developers pass on to the customer. And there isn't like a lot of transparency on what those costs and those profits are" (Interview 15 – NGO). The VOS accounts for previously unaccounted costs and benefits of solar energy under net-meeting. The value of solar tariff includes value from avoided fuel costs, avoided plant operations and maintenance costs, avoided generation, transmission, and distribution capacity cost, avoided environmental cost, credit for local manufacturing, market price reduction, and disaster recovery. Each year, a new VOS tariff is calculated using current data, and the new VOS rate is applicable to all customers entering the tariff during that year. Until 2017, Xcel Energy in Minnesota offered an applied retail rate of 12-15.5 cents per kWh. The switch to value of solar in 2018 dropped this rate down to 10 cents per kWh in 2018 and 9 cents per kWh cents in 2019. In addition to VOS, in 2018 the Minnesota Public Utilities Commission approved a residential community solar adder of 1.5 cents per kilowatt-hour (kWh) for 2019 and 2020. The adder is designed to shift the community solar subscriber base more toward residential customers. The Minnesota Institute for Local Self-

Reliance said that the switch to the VOS rate from the retail energy credit used in the first three years of the program made it difficult to finance projects with residential subscribers, and therefore the adder was necessary to incentivize recruiting residential subscribers (Interview 6 – NGO).. These additional costs come from recruiting and maintaining a residential subscriber base. A representative of the Citizens Utility Board of Minnesota said, "The capital stacks are really different in how they develop projects but it's basically the same outcome. In Minnesota it's super profitable to build these projects" (Interview 15 – NGO). Since Minnesota does not have a program cap, as long as the projects meet the requirements under the rules from the PUC, the projects can be developed. Xcel Energy has to take the electricity generated and pay VOS as projects come online. Diagram A demonstrates financial transactions between Xcel Energy, developers, and project subscribers in Minnesota.

Diagram A: Minnesota's Community Solar Financial Transactions



Colorado

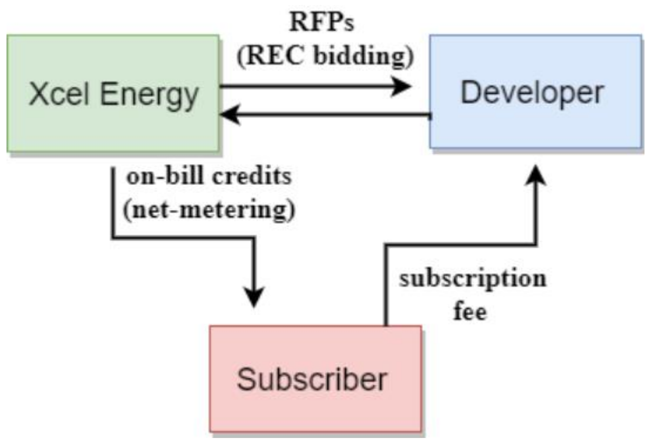
Similar to Minnesota, Xcel Energy in Colorado administers the incentives program. Under the Solar Rewards Community Program, Xcel Energy offers to purchase the energy and RECs generated from qualified solar projects. Under this offering Xcel Energy issues an RFP seeking bids from developers to build solar projects between 10.1 kW - 2 MW in size (Xcel Energy, 2019). These bids must include a REC incentive price, the system location, a summary of the developer’s experience, their financing plan, and the project development plan (Xcel Energy, 2019). The selected bidders must build the projects at the price specified in the developer’s bid. The bid includes compensation that the utility must pay for the RECs and the renewable energy added to the grid (DSIRE, 2019). The most recent solicitation by Xcel was up to 14 MW of project development for 2019. Xcel Energy also launched a separate RFP process for community solar projects that are 100 percent low-income. The bidding process works similarly to standard projects. The first bid is offering up to 4 MW that will benefit Xcel’s low-income customers (Xcel Energy, 2019). A representative of Xcel Energy in Colorado explained the RFP process:

> Today the design of community solar gardens in the state is that the utility compensates the developer for the energy and RECs. So that's essentially what they bid on as solicitation. And that's the main economic criteria by which we evaluate their bids. The incentives Xcel pays to developer come from the renewable energy standard adjustment clauses we have in state. So it’s a rider on everyone's bill in our service territory (Interview 13 – PVT).

In Colorado the community solar subscriber is compensated via a bill credit. The on-bill credits are referred to as net-metering. That bill credit, which is prescribed through statute and rules, equals the cost of generation less the cost of delivery. A representative from Xcel Energy in Colorado said, “Xcel is buying energy in the two to three cent range and subscribers are being compensated upwards of seven cents. So if you get a credit for about seven cents you're getting that benefit. Essentially you're buying energy that normally costs 12 cents you're buying it for five”

(Interview 13 – PVT). Diagram B demonstrates the financial transactions between Xcel Energy, developers, and project subscribers in Colorado.

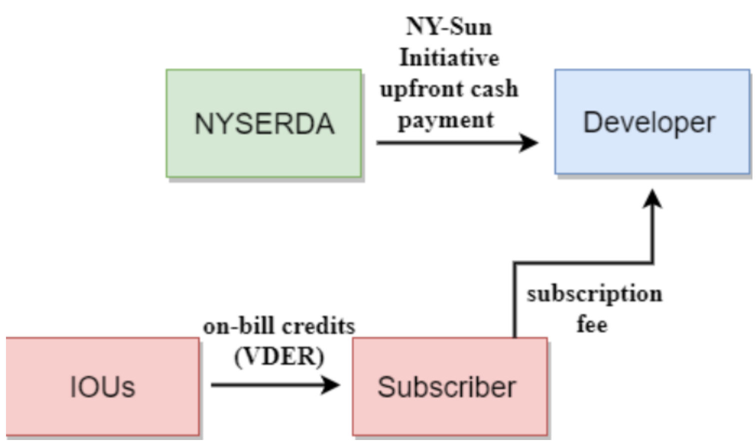
Diagram B: Colorado's Community Solar Financial Transactions



New York

NYSERDA provides financial incentives and financing options through the NY-Sun Incentive Program to support the development of a solar market and industry in New York. Community solar has become a major part of the solar industry. The incentives are currently at 20 cents a watt, but it was previously higher (NYSERDA, 2019). A private developer in New York described the incentive design: "It's just the amount of money per system size and different per zone. You get a cash rebate upfront based on the system size" (Interview 3 – PVT). A representative of NYSERDA explained why these state incentives are critical in financing community solar projects, "The developers wouldn't be able to build the projects by and large without the incentives. But the project economics that they're trying to make work include being able to offer solar power to their customers at a discount to their utility rate" (Interview 14 – GOV). A community solar developer that operates in several states, including New York, explained how community solar projects are financed, “There's a whole host of incentives. So state and federal. There are multiple things that are able to allow us to be able to deliver that benefit. This is kind of the holy grail of clean energy we've been looking for a long time” (Interview 9 – PVT). The New York Public Service Commission is in charge of the tariff structure and the price of the solar energy compensation paid by the IOUs. New York state has a bill surcharge that pays for the clean energy programs (NYSERDA, 2019). The price the IOUs in New York paid for the solar energy acquisition was previously based on virtual net-metering tariff. However, in 2017 New York introduced the Value of Distributed Energy Resources (VDER). VDER is based on a value stack tariff that includes locational-based marginal pricing (ie electrical load zone, demand, and fuel prices), capacity, environmental value, demand reduction value, and locational adders. Locational-based marginal pricing (LBMP) fluctuates depending on when the solar electricity is sent to the grid (New York Public Service Commission, 2017). The value of RECs in New York are under the environmental value component of VDER. According to National Grid in New York, “The credits from the host generator get distributed based on whatever the host application states. So there's [subscribers] that they have to supply us with [and] as long as they're qualified offtakers they can receive those credits from that host generator” (Interview 7 – PVT). Community solar projects interconnected before March of 2017 are paid at the full retail rate. The residential and small commercial or non-demand subscribers will continue to be paid full retail rate until 2020. Everyone else is going to be on the VDER value stack (National Grid, 2019). A National Grid representative described the VDER value stack, “It’s a bunch of components that more accurately reflect the cost of electricity and the social benefits of having that generator located at that particular site” (Interview 7 – PVT). According to a representative of the NY-Sun initiative, the compensation structure is much higher for small non-demand project subscribers, “There was a strong economic motivation to include up to 100 percent residential customers. The policy was adjusted [May 2019] by the Public Service Commission to put commercial customers and residential customers on kind of equal footing in terms of compensation" (Interview 10 – NGO). As previously mentioned, NYSERDA also manages a low-income community solar program called Solar for All. Under the program, NSYERDA issues an RFP for developers to allocate a percentage of their project for low-income subscribers, who would sign-up through NYSERDA and not with the developer. NSYERDA places qualifying subscribers into community solar without any fees. A representative for NY-Sun Initiative explained, "Many developers chose to try to take part in the Solar for All program so there's a competitive request for proposals for developers to basically build capacity or commit capacity to the program. And the state via NYSERDA would be paying the cost. So is a strong incentive" (Interview 14 – GOV). Diagram C demonstrates financial transactions between NYSERDA, developers, IOUs, and project subscribers in New York.

Diagram C: New York's Community Solar Financial Transactions



Massachusetts

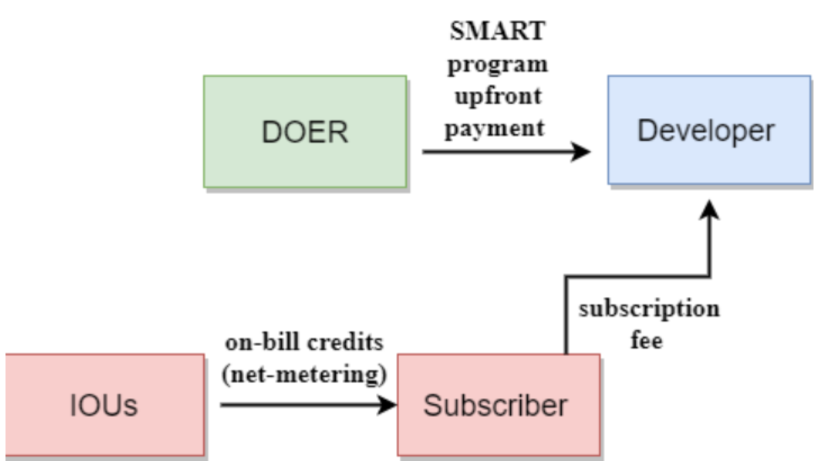
Massachusetts community solar incentives are managed by the DOER, though this responsibility might shift to the utilities in the future. The incentives are based on RECs and other various renewable and environmental benefits associated with them. The first program was the Solar Renewable Energy Credit (SREC-II) launched in 2014. Under the SREC-II program, for every MWh of electricity that a solar energy system produced, a corresponding SREC was created. Similar to how RECs are bought and sold, SRECs can be bought to count toward renewable electricity as part of Renewable Portfolio Standards. Projects were eligible to generate SRECs for 10 years with a decline in state incentives over-time. The SREC-II program reached a cap on the number of solar projects it could incentivize, which prompted DOER to develop the SMART program. Under the SMART program developers receive a payment from the state for their solar production at a fixed rate per kilowatt-hour (kWh) of solar energy produced throughout the duration of the project. The compensation, or all-in rate, that the project developer receives is calculated by subtracting the value of the energy (determined by electricity rates) from the total incentive amount. How much developers earn through the SMART program depends on utility territory, the block they are eligible for, how much solar energy the project produces, and the type and size of the solar panel installation. The total per-kWh incentive can be increased with adders for a few different circumstances (location of installation, type of subscriber, and battery storage). A representative of DOER explained:

> Effectively you get your base rate and then you can apply for community solar which is another five cents per kilowatt hour or a low-income community solar which is another six cents per kilowatt hour…We have a decline in the base rates that we offer through the

> SMART program. Each utility service territory has separate blocks and those blocks declined by 4 percent. The community solar adder is five cents but we establish tranches. After the initial 80 MW every 60 MW of community solar rate declines by 4 percent (Interview 5 – GOV).

The SMART incentives are recovered from a line item on the utility bill (DOER, 2019). The SMART incentives are separate from net-metering, and therefore community solar subscribers are eligible to receive net-metering. However, SMART incentive payments will not include the value of energy if the subscribers receive net-metering credits. Massachusetts has a cap on the amount of solar that is eligible for net-metering. This cap varies depending on the utility company and whether the system is publicly or privately owned. Net-metering does not cover 100 percent of the monthly electricity bill because of applicable charges and fees by the utility provider. Net-metering tariffs are managed by the Department of Public Utilities (DPU). Diagram D demonstrates financial transactions between DOER, developers, IOUs, and project subscribers in Massachusetts.

Diagram D: Massachusetts' Community Solar Financial Transactions



B. Actors

Community solar programs involve several different types of stakeholders. Some of the involved actors are consistent in all four programs. This includes developers, subscribers, state PUC, nonprofits, financiers, and IOUs. Some states have tasked a government agency with managing the community solar incentives. Each state has the public utilities commission (PUC) regulating state net-metering tariffs or other variations of renewable energy compensation. A representative of the Colorado Energy Office outlined the general role of the PUC, “The commission itself is a non-advocacy organization in that it doesn’t take positions. Its role is to look at what is filed before the commission and through the adjuratory process of having a utility file and having intervenors oppose and make recommendation, the commission should find that there is a public interest in reaching a particular conclusion” (Interview 1 – GOV). Regulated state utility companies are typically required to participate in community solar, though some of the smaller IOUs are exempt. Community solar projects under the state programs also involve several private stakeholders. A private developer explained the process:

> There are developers, there are operators and there are financiers. Financiers are companies that just come and finance for a return. The developers are typically guys who develop everything until the point of construction and then kind of catch up early and walk away. And then there are the operators who are kind of paying the developers to walk away and they keep the assets and they operate it for a smaller margin than had a developer financed it. Developer extracts value (Interview 3 – PVT).

Another key stakeholder group are the nonprofit community solar advocacy groups. These organizations often work with private developers to assist with customer acquisition, especially residential and low-income customers. Solstice is a nonprofit advocacy organization that works to alleviate community solar access barriers in Massachusetts and New York (Interview 10 – NGO). The organization fills in the gaps for low-income customer acquisition and works to improve processes and customer management for private developers (Interview 10 – NGO). A representative for Solstice said:

> We use a combination of in-person organizing of referrals and digital marketing to help get the word out about projects and help get folks subscribed. We work directly with solar developers on contracts and then offer those contracts between the developer and the customer. In addition to that we do ongoing customer management which again is a huge piece of the puzzle. Often we are seeing really unfortunate experiences where solar developers were great at developing solar projects but don't have an interest or capacity to provide ongoing customer support and service (Interview 10 – NGO).

The last important stakeholder group for all four community solar programs are the community solar project subscribers, who help to finance the projects. Subscriber is a general term used for all eligible participants who receive a benefit from a portion of the energy generation from a community solar project. Eligible subscribers are utility ratepayers that can include: residential customers, housing authorities, commercial customers, industrial customers, nonprofits, businesses, and other public institutions (e.g. schools). These subscribers are separated into two groups: large and small customers or by the portion of their solar subscription (larger customers subscribe to more solar output).

Minnesota

Xcel Energy, the largest IOU in Minnesota, is tasked with program administration. A representative from Minnesota Department of Commerce described the role of Xcel Energy: “Xcel administers their program. Now admittedly they administer a program that they don't have a tremendous amount of control over. The rules are set up by statute and they have to administer a program that the rules are written for” (Interview 4 – GOV). The administration process entails engineering analysis and technical evaluation of the proposed community solar projects, project interconnection, and VOS payments for the energy acquisition. The PUC in Minnesota is in charge of regulating the projects and ensuring Xcel Energy and the developers are adhering to the rules. The commission approves the process of building and interconnecting community solar projects as well as the VOS tariff and fees associated with project interconnection.

Colorado

Similar to Minnesota, Xcel Energy in Colorado was tasked with community solar program administration, but in a different capacity. A representative of Xcel Energy in Colorado describes their role:

> Being the program administor we suggest to our commission what range and capacities we think would be acceptable for the program which basically is a minimal amount and the maximum amount. Right now we're operating around 40 MW as the maximum amount.

> And from there we do a competitive solicitation for and look at a number of criteria mostly economic. But then there are other variables we do look at like our experience with a developer. We run that solicitation and then we issue awards to the bids up to the maximum amount (Interview 13 – PVT).

In Colorado the PUC determines what is reasonable for market size and what is reasonable for customers to pay and what preserves the overall health of the utility (Colorado Energy Office, 2019). The PUC regulates the net-metering tariffs that Xcel Energy pays as bill credits to subscribers of community solar projects.

New York

In New York, NYSERDA administers the NY-Sun initiative, which is a one-billion-dollar state program. As part of the program, the government agency administers the incentives for community solar projects. A representative of the NYSERDA NY-Sun Initiative explained:

> NYSERDA provides a lot of technical assistance to different market participants. Perhaps most importantly we work a lot with local governments and authorities to develop zoning and permitting processes for solar including community solar and support them as a solar companies kind of come to town and start to build solar projects. We also do a lot of customer education and we also assist our state regulatory agency the Department of Public Service on issues such as project interconnection and other market topics (Interview 14 – GOV).

In New York, the IOUs have a minimal role in community solar and therefore do not list this option on their company website. National Grid, one of several IOUs in New York, said that their role is strictly with interconnection and technical requirements. "[National Grid] strictly take the applications, make sure they're correct, and then move through with the interconnections" (Interview 7 – PVT). The Public Service Commission (PSC) of New York puts forward community solar rules and regulations that IOUs and developers have to abide by. Similar to other states, the PSC oversees rules regarding tariff structures for VDER.

Massachusetts

The community solar program in Massachusetts is administered by the DOER. The government agency is responsible for developing the incentive structure (SREC-II and SMART) and paying community solar developers. The Department of Public Utilities (DPU) regulates the IOUs and oversee the net-metering program that community solar subscribers are eligible to participate in. Solar developers and IOUs in Massachusetts have a similar role as they do in New York's program. The IOUs are only responsible for interconnection of projects, though the IOUs actively participate during DPU hearings to propose changes or amendments to the community solar program. A representative of DOER said that the majority of community solar projects are from private developers.

C. Interactions

The actors in community solar programs are tasked with program operations based on the written rules. The variation in rules across the four state programs has resulted in different interactions for each program.

i. Minnesota: Program design puts developers in a beneficial position

The configuration of the community solar program in Minnesota leads to developers receiving most of the financial benefit and leaving their subscribers with modest electric utility savings of about four percent. The program does not have any significant restrictions on the subscriber mix between commercial and residential customers. The restriction that a single subscriber cannot take more than 40 percent of the total energy output has not prevented commercial customers from crowding out the residential and low-income customers. Moreover, the program does not have a low-income provision to allow for greater participation of low-income customers. The programs strive to balance subscriber type by mandating a minimum and maximum number of subscribers per project. In Minnesota, the current minimum is five subscribers per project, which in conjunction with no subscriber type restrictions leads to large customers crowding out the residential and low-income customers.

The lack of a program cap and attractive incentives for developers has flooded the market with private developers, many coming out of state, to build and sell projects. Xcel Energy in Colorado commented on the community solar market in Minnesota, “Minnesota has been very wide open and that's been kind of the wild wild west on development” (Interview 13 – PVT). The Citizens Utility Board of Minnesota also confirmed the rapid development in Minnesota, “They're just building at a frantic pace. And customers are being compensated at like a full retail rate. And then the developers are taking most of that rate” (Interview 15 – NGO). The design of the community solar program in Minnesota seems to benefit the developers the most, who are able to take advantage of the flexible project development rules, with no program cap and no subscriber mix restrictions. The flow of finances in Minnesota community solar projects results in developers charging high project subscription fees and taking away most of the VOS benefit that is compensated to the subscriber by Xcel Energy. The lack of transparency and oversight in what transpires between the developer and the subscriber in the signed contracts means that the developer can charge a high subscription fee and take away most of the benefit the subscriber receives from VOS on-bill credits. Moreover, since RECs are given to Xcel Energy as part of VOS, the additional revenue that might be generated from RECs to fund community solar projects is lost. The subscription fees are one revenue stream to fund the projects. The original intention of giving subscribers high on-bill credits to see substantial savings is lost through the community solar project participation fees. A representative of the Citizens Utility Board of Minnesota said, “In Minnesota they're making money hand over fist and so there should be an ability to pass on more savings” (Interview 15 – NGO). The difference between the on-bill credits commercial and residential subscribers receive is not significant enough to incentivize developers to acquire more residential customers. The residential adder that was recently implemented is too low to offset the cost of residential customer acquisition for developers. The developers find large subscribers who take a larger portion of total project capacity to be cheaper to acquire and more reliable. The modest savings passed to the subscriber are much more beneficial for large customers, who are able to subscriber to a larger proportion of community solar energy and receive large amount of electric bill savings.

The design of the community solar program in Minnesota presents barriers for developers to include more residential and low-income subscribers as well as participation barriers for those customers. The lack of an upfront cash payment to the developers in Minnesota makes it more difficult to finance projects with residential and low-income subscribers, resulting in developers going after larger customers, such as commercial. The subscription contract fees are a persistent form of a financial barrier for residential and low-income customers, who typically cannot afford an upfront cash payment. The burdensome application process, receiving two separate bills, upfront application fee, and small savings present possible barriers for residential and low-income customer participation. The lack of a subscriber mix restriction and no residential and low-income incentives for developers to acquire that customer base, has resulted in developers making large profits from subscribing mostly commercial customers.

Minnesota's community solar market without a cap on program size and lack of developer regulation has favored the developers. In turn, the developers have flocked to Minnesota's community solar market to build as much as the market allows and take most of the financial benefit. Xcel Energy has no choice but to interconnect projects as long as they meet the minimum qualifications. The outcomes section outlines how the program design and incentives of community solar in Minnesota resulted in rapid program growth but not given much access to residential and low-income customers.

ii. Colorado: Utility controls program growth

The community solar program in Colorado is administered by Xcel Energy, who has constrained the market through the RFP process and created an overly competitive program for developers. The RFP process in Colorado has contributed to a much slower program growth than in Minnesota. In Colorado, Xcel Energy has a lot more control over programmatic oversight and how fast the program grows. The utility decides on how much additional capacity of solar they're willing and able to take on. The main component of the RFP process by which Xcel Energy grants awards is the price at which the developers are willing to sell the RECs to Xcel Energy. This process has led to a situation where the lowest bidder wins a development contract with Xcel Energy. A representative of Colorado Energy Office said, “What the developers have said was essentially the limited size of the market means that the utility controls who wins. We have to give [Xcel Energy] the best possible price and the best possible price is we're going to pay them to take our solar” (Interview 1 – GOV). The overly competitive RFP process for developers has driven the price of RECs into the negatives and effectively stalled program growth. In 2019, Colorado legislature increased project capacity from 2 MW to 5 MW to make project financing easier and spur program growth. Colorado Energy Office said, “The two MW size really didn't allow developers to capture scale and that may have created both a cost burden to developers and potentially an artificial limitation in market size” (Interview 1 – GOV). The limited community solar market and the utility controlling who wins the development contracts created an artificial market benefiting the utility. The developers were forced to drive prices so low that some of the approved projects may never get build.

The flow of finances in Colorado comes from the price of RECs developers receive from Xcel Energy as well as the subscription fees developers charge project participants. The competitive bidding process has brought the price of RECs so low that developers have to recover their costs from higher project subscription fees. Similar to Minnesota, developers in Colorado do not receive an upfront cash payment from the state, which makes financing projects more difficult. The subscribers receive on-bill credits from Xcel Energy in the form of net-metering, but the rising project subscription fees subtract from the net-metering benefit. Since customer acquisition adds extra project cost and the developers are looking to propose the least costly project, this leads to less inclusion of residential and low-income customers. A developer in Colorado gave their company's perspective on the RFP process: "If it's an RFP then the developers like us don't like it because it gets really difficult to make projects work financially. But it can be a good way for a state to drive down the cost. The trick is sometimes the bidding prices in RFPs are so aggressive that the projects don't ever ultimately get built" (Interview 2 – PVT).

The community solar program in Colorado has similar subscriber mix participation rules as Minnesota. The only subscriber restriction in Colorado's program is that a single subscriber cannot take more than 40 percent of project energy capacity. As previously discussed, this type of restriction does not prevent commercial subscribers from crowding out residential subscribers. Since the profit margins for developers are tight, it's much more beneficial for the developer acquire mostly commercial subscribers, who are cheaper and more reliable subscriber base. The program in Colorado does have a low-income provision, which requires that five percent of each project's energy capacity must be subscribed by low-income customers. The low-income provision in Colorado has successfully allowed for low-income participation. However, low-income participation has only met the minimum requirement of five percent.

iii. New York: Obstacles to program growth

New York's community solar program has experienced several obstacles to growth that include a complex incentive structure and the 60/40 subscriber mix provision that restricts developers from acquiring commercial customers. The VDER value stack involves too many changing variables that include energy value, capacity value, environmental value, demand reduction value, and locational system relief value. The subscriber mix provision in New York is the most restrictive to commercial participation out of the four programs. The design of the upfront cash payment to the developers forces the developers to acquire residential customers because the state incentives for residential subscribers are much higher than commercial and make financing of projects easier. According to NYSERDA, “There was a strong economic motivation to include up to 100 percent residential customers” (Interview 14 – GOV). The flow of finances in New York comes from the upfront cash payments to the developer and the on-bill subscriber credits (VDER) which make project economics. The incentive structure gives a larger discount to the subscriber and often times allows developers to not charge upfront subscription fees.

Despite the attractive incentives from the NY-Sun initiative, which gives an upfront cash payment to developers, community solar growth in New York has lagged behind other states. The Institute for Local Self-Reliance described the complexity of rules in New York, which have contributed to slower program growth, “New York tried to be very accurate in determining what the value of solar energy was like. They came up with a really complex formula with all these moving pieces and it was a failure in a way because by being so accurate they really made it hard for projects to develop” (Interview 6 – NGO). New York’s attempt to create a precise value of solar energy created roadblocks for developers. A private developer in New York shared this sentiment:

> There was a solar summit in New York and one of the keynote speakers was formerly a derivatives bond trader on Wall Street and his comment was that selling the value stack in New York is more complicated than that. It's just very difficult. Anything to simplify the cost structure would be an enormous help. But it just keeps changing and each attempt to make it simpler tends to just complicate things (Interview 11 – PVT).

Projects with predictable returns are easier to finance (Chang et al., 2017). The complex incentive structure in New York creates predictability barriers for developers. Chang et al. (2017) study identified additional program complexity in New York with their queue-based application system for developers. The original design for developer applications blocked the system due to poorly completed applications that were creating a bottleneck. The rules were amended to create stricter requirements for developers, which will drop the applicant out of the system if the application does not meet the strict requirements. The stringent application rules for developers is an example of another blockage to growth. Since the passage of the community solar policy in 2015, New York has built 40 MW capacity of community solar. However, the state currently has 800 MW in pipeline that has not yet been built.

The complexity of the cost structure is one challenge. Another challenge in New York is customer acquisition. New York's policy has a subscriber mix provision that requires the projects to have at least 60 percent small or nondemand customers. New York defines a demand customer whenever a customer's energy consumption exceeds 2,000 kWh/month for 4 consecutive months (National Grid, n.d.). The state incentives are also higher for non-demand customers. The rules heavily incentivize developers to acquire mostly residential customers because it would not be profitable for them to acquire commercial or other demand customers. However, New York state has a history of bad relationships between energy companies and residential customers, particularly with low-income customers. A private developer in New York shared this sentiment:

> There's significant customer distrust for utilities and energy companies in general. We have a long history of bad business practices, especially by ESCOs scamming people. Offering discounts and increasing rates dramatically. A lot of people lost a lot of money and lost faith in the energy industry (Interview 11 – PVT).

Another developer in New York stated that the community solar rules ensure that projects are going to residential customers, "In New York the majority of the projects that are going online now have to be residential because you will not be able to make a return on your project if you [have] commercial because you get paid at a lower rate" (Interview 9 – PVT). The rules in New York have limited commercial customer participation in community solar, but at the same time it has also stalled program growth because it doesn't allow developers to use commercial customers as project anchors. The community solar rules in New York have created a bottleneck.

iv. Massachusetts: Program acceleration

The community solar program in Massachusetts is flexible enough to allow for large program growth, but it also restricts some commercial participation, creating a balance between commercial and residential subscribers. The design of the community solar program in Massachusetts is somewhere between Minnesota and New York in terms of program design flexibility. Community solar program oversight is managed by both the DOER and the DPU. The agencies have designed a program with high enough incentives for rapid growth, but also flexible enough to allow a balanced mix of commercial and residential subscribers. A representative of the DOER said:

> We had a specific way that the net-metering credits had to be divided to qualify. A lot of the community solar projects that we see qualified in Massachusetts systems may have one single large commercial offtaker that's taking half of the energy and the remainder has to be divided into smaller dividends. The other tends to be divided among residential offtakers (Interview 5 – GOV).

The incentives for developers in Massachusetts come from the SMART program (previously SREC-II). These incentives are separate from the on-bill credits the subscribers receive from net-metering that offset some of the costs associated with subscription fees and utility bills. The dual flow of incentives creates cashflow for develops to build and allow subscribers to participate for a low to no cost. The developers in Massachusetts are able to provide their subscribers with a guaranteed monthly utility bill savings of 15 percent. The subscriber mix provision in Massachusetts allows the developers to include commercial subscribers as project anchors and to allocate the rest of the energy capacity to residential subscribers.

D. Outcomes

The repeated interactions among the program rules and actors have resulted in unique program outcomes in terms of residential and low-income access for the four programs.

i. Minnesota: Minimal residential and low-income access

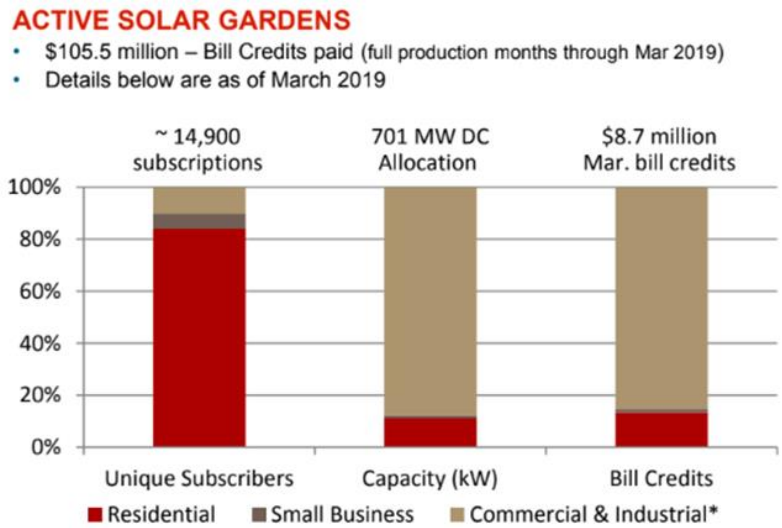
The community solar program in Minnesota has flexible rules that allow for rapid development and program growth, but the rapid growth has led to projects being subscribed by mostly commercial customers over residential customers, while also increasing energy costs for all Xcel

Energy ratepayers. This means that the benefit subscribers receive from VOS is mostly going to commercial customers who are crowding out the residential customers from participating. According to Institute for Local Self-Reliance, the program in Minnesota is flexible to allow for large development, “No cap on the program to allow for development to be flexible and as large as the market would carry to provide distinct and real financial benefits to participants” (Interview 6 – NGO). However, the rapid growth has contributed to the high cost of energy acquisition for Xcel Energy. The high cost Xcel is paying for solar energy are recovered from all atepayers, who may or may not participate in community solar. A representative of Xcel Energy explained:

> In Minnesota last year eight percent of our fuel cost that's passed on to all of our customers went to supplying one and a half percent of our energy that came from community solar gardens. Given the number of gardens currently in process by 2020 four percent of our energy will come from community solar gardens and paying for that energy will be 21 percent of our fuel cost…having an unlimited cap on the size of aggregated purchases without having some sort of market driven pricing mechanism goes beyond how anyone typically buys power. The impact of that on all of our customers through the price they pay is ever exceeding. The cost is too high and there is too much of it (Interview 12 – PVT).

Moreover, Minnesota’s community solar program does not have restrictions on the subscriber mix, which further contributed to most of the energy capacity going to commercial customers. Figure 5 was obtained from Xcel Energy and depicts the breakdown of the subscriber mix and who is receiving the benefit of community solar program:

Figure 5: Xcel Energy Community Solar Subscriber Mix and Bill Credits Allocation



Source: Xcel Energy Minnesota, 2019

Figure 5 shows the financial benefit paid by Xcel Energy in the form of bill credits going to commercial and industrial customers. However, Xcel's entire ratepayer base is paying into the program in the form of a line item on their utility bills. Therefore, those who do not participate in the community solar program will see higher utility bills, which has mostly fallen onto residential and low-income subscribers who are less likely to participate in the program. The design of the program does not incentivize residential and low-income participation and the contract complexity between the project developers and subscribers creates a burdensome process for residential and low-income customers to join. The minimum requirement of five subscribers per project creates a situation where developers are going after large customers because customer acquisition is easier and cheaper, which lowers the overall project costs. Community solar program design in Minnesota has successfully accomplished solar market growth in Minnesota, but the benefits in the form of bill credits have not been distributed equitably. A representative of Solstice explained, "[The developers] best interest is to acquire a smaller number of customers and pay less money for acquisition and that can definitely mean that they might go in the direction of maxing out the commercial or small commercial entities versus individual households" (Interview 10 – NGO).

Additionally, not having a low-income provision or a mechanism by which to encourage low-income participation is an example of financial and institutional barriers that hinder low-income access. A representative of the Institute for Local Self-Reliance confirmed these challenges: "I think on lower income our program is not successful. Most of the subscription models are either that you pay upfront which would be difficult for a low-income household or that if you have a good credit score you are able to pay your subscription simultaneous with getting the benefits" (Interview 6 – NGO). The design of the community solar program has not eliminated the need for a high FICO score of 650+, which creates a barrier for low-income customers, who on average have a lower FICO score. Nonprofit organizations such as Solstice are working to alleviate these barriers. Solstice is testing a new mechanism by which to qualify low-income customers called energy score, which could serve as an alternative credit metric for low-income customers. The low participation of residential and low-income customers is significant because they still end up paying for the program, as indicated by a representative of Citizens Utility Board of Minnesota: "Ratepayers are paying something like 140 to 170 million dollars annually to support community solar these are non-participating customers. And there's almost no benefit. It's a huge cost shift from ratepayers through the utility to the developer for 1 cent reduction in cost for residential customer" (Interview 15 – NGO). The lack of a low-income provision or an adder has resulted in nonprofit organizations working on outreach efforts to help residential and low-income customers understand the benefits of the program and encourage program enrollment. A representative of Citizen's Utility Board of Minnesota said:

> Minnesota doesn't have a low-income provision. And so there are folks doing low-income work here. But there is no specific policy approaches or fixes relative to low-income specific customers. Minnesota low-income community solar is almost nonexistent. There are two projects. And if you look at the 800 MW of either installed or dedicated capacity in Minnesota that's less than one percent of the total generating capacity (Interview 15 – NGO).

Xcel Energy reached a settlement with Minnesota PUC in 2019 to incentivize low-income solar development. Xcel Energy reserved $1 million out of the $10 million for income-qualified customers. However, these incentives are not part of the community solar program (Minnesota Department of Commerce, 2019).

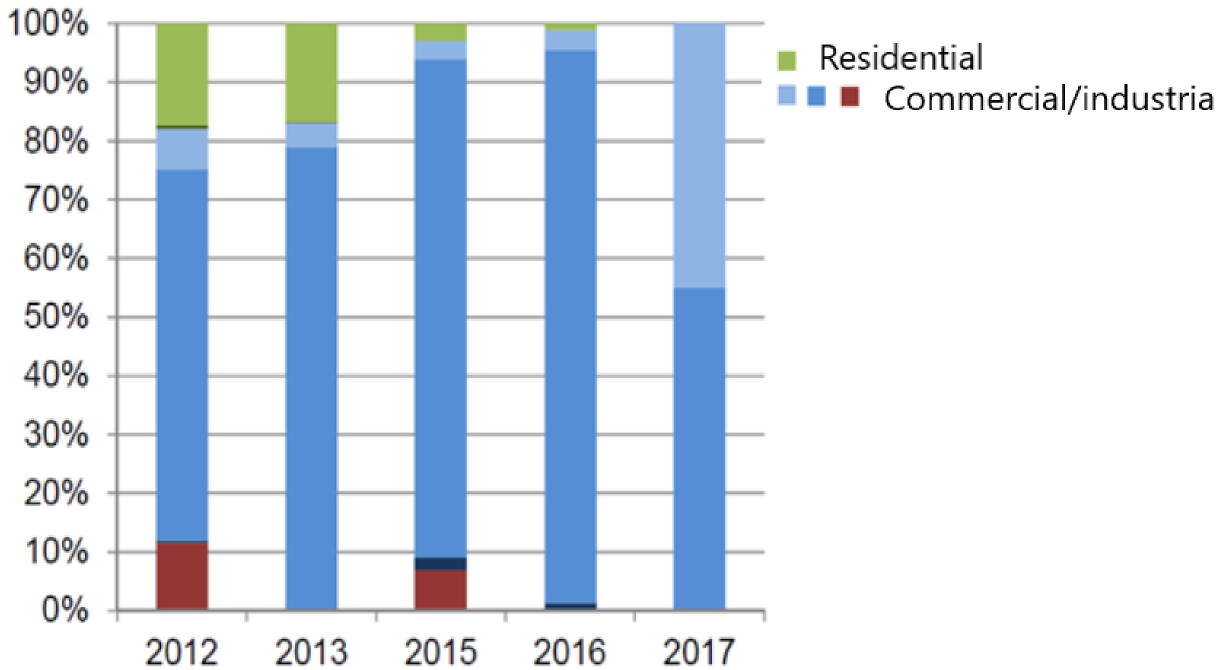
ii. Colorado: Minimal residential and some low-income access

Community solar program design in Colorado has resulted in an aggressive RFP process that has driven the price of RECs into negatives and makes financing of projects difficult. The aggressive bidding process has also resulted in developers acquiring mostly commercial subscribers. A representative of Xcel Energy in Colorado gave insight into their community solar subscriber mix:

> By capacity they're larger customers; a lot of municipalities, schools, large commercial customers take up the most capacity. By capacity it's definitely going towards larger customers. Part of the component of this rulemaking is to strike a better balance for residential customers because that is actually something as listed in the law to you know to try to serve low-income and renters specifically (Interview 13 – PVT).

Figure 6 demonstrates the subscriber mix in Colorado by energy capacity from community solar. The figure was obtained directly from Xcel Energy.

Figure 6: Xcel Energy Community Solar Subscriber Mix



Source: Xcel Energy Colorado, 2019

Despite low residential participation, the low-income policy provision has succeeded in accomplishing a five percent low-income participation. However, some advocates argue that the provision is not entirely effective because the five percent requirement created a ceiling when it was intended to be a floor. A representative of Colorado Energy Office stated:

> We did a report at the Colorado Energy Office on low-income participation in community solar and what that report found was that the carveout was being met but no additional low-income solar offerings were being made. Essentially that carveout became a cap or a ceiling for participation (Interview 1 – GOV).

Colorado's low-income provision of including five percent low-income subscribers per project presented significant challenges to private developers who previously did not have experience with this type of customer base. Therefore, the policy did not meet the exact intention of low-income customers participating in the program. It became easier for developers to give out the five percent subscriptions for free to low-income customers rather than asking them to pay a subscription fee. A representative of Colorado Energy Office explained:

> What we've found out is actually no low-income people were using their own money to participate. The developers taking 100 percent of the cost of the garden's spreading over 95 percent of the customers. And then just keeping away that 5 percent subscription…The trouble for developers in Colorado was [they] don't have any expertise to deal with these populations. And we built a business model that is really dependent on and serves the commercial and industrial customer and residential was hard enough. It was costing them enough money at low-income was even more challenging (Interview 1 – GOV).

Since community solar developers do not have experience with low-income customer acquisition, it became apparent that mandating them to deal with this group of subscribers was not the most efficient way of ensuring low-income participation in community solar projects. Therefore, Xcel

Energy reached a settlement with the Colorado Public Utilities Commission to host a second type of community solar program that would be for 100 percent residential low-income subscribers. Xcel Energy understands the low-income ratepayer base better than the solar developers and has more experience serving them. In 2019, Xcel Energy allocated 4 MW out of the 40 MW for low-income community solar development. A representative of Colorado Energy Office said, " Xcel and a couple other parties reached a settlement in Xcel's resource plan in which Xcel said of the 40 MW annually that they were going to develop 10 percent of that would be low income. They said we'll take the five percent requirement and we'll develop it ourselves" [Interview 1 – GOV). This move by Xcel Energy is significant because according to Colorado Energy Office one in three Colorado residents falls under the low-income bracket.

iii. New York: Residential and low-income access

Community solar program design in New York makes it difficult for developers to acquire residential customers, but despite the design, the program incentivizes residential and low-income access if the developers are able to recruit them. The incentive structure has gotten increasingly complex, contributing to the difficulty of residential subscriber acquisition. The design of community solar in New York has created a situation where developers have to acquire mostly residential subscribers, but they're having a difficult time because of significant customer mistrust from past experiences with energy companies. Therefore, the complexity of the VDER value stack and 60/40 rule has created significant barriers for developers to proceed with planned projects, resulting in pipeline blockage for planned projects. This might lead to a bottleneck effect of turning developers away from the New York community solar market. Private developers in New York confirmed slowed program growth:

> There are very few developers who have more than a couple of projects actually energized and operating in New York State…There are a lot of community solar arrays in New York that are ready to be built even projects that are built and ready to be energized and cannot be because they're not subscribed. So that's a major barrier in New York (Interview 11 – PVT).

Despite slow program growth, New York has successfully designed a program that incentivizes community solar access for residential and low-income customers. The incentive structure and 60/40 rule has limited demand customers from participating, which are typically used as project anchors. The incentive structure from the NY-Sun initiative gives an upfront payment to developers and the on-bill credits (formerly net-metering and now VDER) create a large enough incentive for developers to guarantee their subscribers a 10 percent monthly savings on their utility bills and the disclose form placed on top of contracts makes finances easier for subscribers to understand. The high incentives for developers also allow them to lower their subscription fees. However, lack of consolidated billing means that subscribers have to receive two bills, one from utility and another from the developer. A representative of NYSERDA responded that the subscriber type data is not aggregated by any party in New York and the agency does not collect data on individual community solar subscribers. However, the agency shared a spreadsheet that lists all community solar projects funded by NYSERDA and the vast majority of these are residential (New York Office of Information Technology Services, 2019). New York has also seen success with residential low-income participation in community solar projects. A developer in New York explained NYSERDA's role in low-income customer acquisition for community solar projects and how it has helped developers: “[Solar for All] removes all of the customer acquisition costs for the developer and that seems to be the real pain for developers right now. It's a huge relief I think for those projects to assign you know a really substantial portion of them to customers” (Interview 11 – PVT). NYSERDA’s Solar for All Program that targets residential low-income customers has been so popular that they have to issue an RFP bidding process. One developer shared their perspective on the low-income program in New York: “My take on it is that large scale developers are having such a difficult time finding subscribers for their projects that they are desperate for programs like that where they can assign a huge portion of an array to a program and not have to worry about customer acquisition” (Interview 11 – PVT). Even though New York successfully designed a program that encourages residential and low-income participation, developers are experiencing challenges with the complexity of VDER and filling their projects with all residential subscribers. As a result, New York’s policy was recently changed to allow for more commercial participation to accelerate development and program growth.

iv. Massachusetts: Commercial and residential access

The community solar program in Massachusetts has witnessed rapid growth, and under each incentive program structure from the DOER, the program met solar development goals ahead of schedule. Community solar in Massachusetts has grown to 1,200 MW of installed and approved capacity, which is 47 percent of the solar capacity in the state. The incentives in Massachusetts are high enough (SMART and net-metering) and the program design has achieved a balance of precision and flexibility to allow for sustained program growth and a mix of commercial and residential subscribers. Community solar in Massachusetts has reached market maturity and the incentives are set to decline. DOER does not currently have a central database that tracks the type of subscribers that participate. However, according to stakeholders involved with community solar, the subscriber mix is balanced between residential and commercial. One developer in Massachusetts said, “[In] Massachusetts you have a combination of commercial and residential” (Interview 9 – PVT).

On the side of residential low-income subscribers, Massachusetts is less successful. Massachusetts community solar achieved high participation of low-income housing developments, however the financial benefit of community solar has not reached low-income homeowners and renters that pay their own energy bills. Developers said that the new low-income adder of an extra one cent is not enough to cover low-income customer acquisition costs. According to a developer: “[Massachusetts has] an incentive, a special adder that if you have a low-income program. We have not done that. And the reason we haven't done that is that it's not enough money to justify the extra costs that are associated with running a project. The dollars and cents don't make any sense” (Interview 9 – PVT). Therefore, Massachusetts still needs to work on a mechanism to engage low-income communities and encourage developers to seek low-income subscribers. DOER stated:

> We're actually struggling with what is the best way to engage low-income communities and help them benefit because right now the incentive goes to the solar developer not necessarily to the ratepayer. The design or the intention was that [the developer] would then give a better discount rate to low-income offtakers because they're receiving more funding from the state (Interview 5 – GOV).

Overall, the program design in Massachusetts allows for steady community solar development and the net-metering restrictions ensure that the developers are acquiring a mix of commercial and residential subscribers. Program oversight falls onto the government, which ensures that subscribers and developers are both receiving program benefits. Aside from low-income participation, Massachusetts is meeting its goal of expanding solar access.

VI. Conclusion and Policy Considerations

Community solar programs have emerged as a new financing mechanism by which states can expand their solar markets and increase consumer participation in the solar PV market. Community solar is based on subscription rather than an ownership model, which serves to eliminate financial barriers for residential and low-income customers. Another attractive feature of community solar is the subscribers do not need to provide their own rooftop or land space to participate in the program, which opens up the market to renters and property owners with unsuitable roofs. States such as Minnesota, Colorado, New York, and Massachusetts have been pioneers in the institutional design of community solar programs, but each state has taken a slightly different approach to program design. One policy goal of community solar programs is to expand solar PV access to anyone who isn't able to participate in the solar PV market, but with a specific focus on residential and low-income customers. The distinctive approaches each state took in the institutional design of community solar programs created an opportunity to examine what elements of program design allow for greater solar access to residential and low-income customers.

The four community solar programs examined in this study have allowed for states to expand their solar market growth. For example, Minnesota's solar market grew from 3 MW in 2013 to 1,206 MW in 2019 with community solar accounting for 46 percent of installed capacity and has an additional 381 MW of projects in the pipeline, which puts community solar at 59 percent of all solar installation in Minnesota. Similarly, Massachusetts also used community solar to boost their solar market. When the state launched its community solar program in 2009, it had 10 MW of installed solar capacity. The state now has 2,567 MW with community solar accounting for 23 percent of installed solar energy and an additional 600 MW of development has been approved. Community solar programs in Colorado and New York haven't grown as rapidly due to program design constraints. Colorado's program is constrained by Xcel Energy's RFP process that determines annual development capacity. In New York, the complex VDER structure and rules that incentivize developers to acquire all residential customers have challenged developers in getting the projects fully subscribed and operating. New York currently has 40 MW developed with 800 MW pipeline.

The institutional design of the four community solar programs has resulted in different levels of residential and low-income participation. The main program design elements that seem to impact residential and low-income access are: who administers the program, subscriber type provision, and the incentive design. Programs that are administered by utilities have lagged behind in residential and low-income access. The incentive structure in these programs is determined by the utility (though it is approved by the PUC) and the incentives that the utility creates do not restrict developers from acquiring mostly commercial customers, which serves as a cheaper subscriber base for the developers. In designing the incentives, the government agency or the utility has the option of limiting the number of large vs small subscribers of a single project. Minnesota and Colorado have not placed restrictions on the number of commercial and residential subscribers, which has resulted in most of the energy capacity going to commercial subscribers with limited access for residential customers. Large commercial and industrial subscribers are cheaper for developers to acquire because they need a smaller number of those subscribers to fill up a project. Therefore, when the rules do not restrict how many large or commercial subscribers that are eligible to participate, the developers are financially incentivized to acquire mostly commercial subscribers. However, New York's program demonstrates how program rules that restrict any commercial participation present customer acquisition challenges for developers and impede program growth. New York has successfully designed a community solar program that allows for mostly residential participation, however only when developers are able to find enough residential customers to fully subscribe their projects. Massachusetts community solar program achieved a balance of commercial and residential customer participation. Massachusetts allows commercial customers to serve as project anchors up to 50 percent of project capacity, with the other 50 percent allocated to residential subscribers.

Another subscriber base that's important to consider is residential low-income customers. This customer base disproportionately experiences barriers to participation that include financial, instructional, knowledge, and behavioral. In designing community solar programs, states need to consider a multitude of factors including customer acquisition, upfront costs, subscription fees, and contracts. Tasking the developers with low-income customer acquisition presents challenges to the developers who have limited experience with this customer base. New York's program effectively passed the responsibility of low-income customer acquisition onto a government agency that has the tools to effectively acquire and manage this subscriber base.

For residential and low-income participation, the design of the incentives has to be attractive enough for developers to go after this customer base and be able to guarantee a high enough monthly savings to attract residential and low-income subscribers. Programs that offer an upfront cash payment, such as New York and Massachusetts, are able to guarantee their subscribers a higher percentage savings on their monthly utility bills. The community solar programs in Colorado and Minnesota do not have a state-based upfront cash payment that developers receive, and therefore offer a lower percentage savings to their subscribers. The programs in Minnesota and Massachusetts use higher adders for the on-bill credits to incentivize more residential and commercial participation. However, developers have expressed that these adders are not high enough to cover the customer acquisition costs.

Expanding community solar access to residential and low-income customers is an important issue because the cost of these programs in the form of incentives and other fees comes from the entire utility ratepayer base, whether they participate in the program or not. Therefore, if most of the program incentives are going to commercial subscribes, this becomes an equity issue. Learning from the experience of the current programs, incentives are best structured in a way that allows a large commercial subscriber to serve as a project anchor and the rest of the subscriptions going to residential customers. This balance allows for residential participation but also alleviates subscriber acquisition obstacles for the developers. Overall, community solar programs have the potential to expand access to all types of subscribers, but the institutional design of these programs will determine who participates and benefits from these programs.

A. Policy considerations

The experience and outcomes of the state community solar programs examined here suggests some policy considerations to expand access to residential and low-income customers. The findings show that one important element of program design is to implement better tracking of program metrics to better understand the impacts of community solar programs. This means creating concrete program goals and tools to measure progress toward those goals. If the program goal is to expand solar access, then it would be beneficial to have a mandatory tracking mechanism in place that consolidates all community solar participation data and incentive data. Having a central program benchmark tracking system will allow to amend the program as necessary to meet program goals. For example, community solar programs in New York and Massachusetts are administered by a state agency that does not track their subscriber mix (residential vs commercial) and is also unable to provide a visual representation of who receives the benefit of community solar. A consolidated community solar database would also be beneficial during stakeholder meetings to provide progress toward program metrics.

Another community solar policy consideration is to create a subscriber mix provision that encourages a mix of commercial and residential participation and prevents large customers from crowding out the residential and low-income customers. The importance of this program design element is evident from the experience of the four states in this study. Massachusetts subscriber mix provision allowed for 50/50 mix of residential and commercial subscribers. New York created a provision that disincentivized any commercial participation and created challenges for developers to fully subscribe projects with all residential customers. Meanwhile, Colorado and Minnesota did not create a subscriber mix provision, resulting in commercial customers crowding out the residential customers. The subscriber mix provision can be implemented by restricting on-bill credits for each type of customer, similar to the policy in Massachusetts. Another option is to require subscribers of a project to be X number of commercial vs residential customers.

Another way to expand access to residential and low-income customers is to increase the amount developers receive for each type of subscriber. The current adders in place for residential and low-income subscribers are not significant enough to offset the cost associated with customer acquisition expenses for the developers. Massachusetts recently implemented a low-income adder to the SMART program that's only 1 cent more than the incentive in place for residential customers. Developers have said that this adder is not high enough for them to invest their time and resources to acquire low-income subscribers. Minnesota has also implemented a 1.5 cents VOS adder for residential subscribers. Similar to Massachusetts low-income adder, developers have said that the residential adder in Minnesota is not high enough for them to acquire more residential subscribers.

The transition from net-metering on-bill credits to a more accurate credit scheme such as value of solar requires a clear, transparent, and predicable formula for developers. Overly complex formulas can create confusion and uncertainty for developers. The experience of New York's VDER credit scheme created barriers for developers in calculating the value of community solar energy projects which is based on a complex value stack that includes energy value, capacity value, environmental value, demand reduction value, and locational system relief value. These values can go up and down and complicates long-term predictions. The value stack has proven to be so complex that some program stakeholders prefer to go back to net-metering.

Moreover, to achieve sustained program growth and expand access, community solar program rules should not constrain the solar market. This can be achieved by splitting the role of the program administration among more than one entity. This could be a major utility like Xcel Energy and a government agency. Doing so will ensure that the utility is not controlling market growth. Another policy consideration for program design is to require consolidated billing that includes the utility bill with the community solar subscription fee and on-bill credits. The current systems of receiving two bills creates confusion and deters residential and low-income consumers from participating. Low-income customer participation is one program element that states struggle with. The best tool so far has been to create solar projects that are 100 percent low-income. The Solar for All program managed by NYSERDA is one model by which this can be achieved.

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APPENDIX A:
INTERVIEW QUESTIONS

Dr. David Bernell, Principal Investigator, Oregon State University
Julia Ostapiej, Student Researcher, Oregon State University

Interview protocol for investor owned utilities:

1. Can you please tell me a little bit about your organization's involvement with Community Solar? What aspects of Community Solar is the utility in charge of?
2. What are the goals of Community Solar for your organization?
3. What are the benefits of Community Solar for your organization?
4. Has your organization experienced or currently experiencing any difficulties with state or federal regulation compliance? If yes, what kind?
5. Does your organization receive adequate support from state regulators?
6. Did your organization experience any challenges with integrating energy produced from Community Solar projects?
7. What strategies does your organization use to recruit subscribers? (marketing, campaigns, community outreach/engagement?)
8. Do potential subscribers have access to adequate information? Is Community Solar listed on online for customers to see? **(if applicable)**
9. Does your organization have outreach and marketing material that specifically targets lower-income households? If yes, what aspects does this material highlight?
10. Is the electricity rate subscribers pay lower, equal to, or higher than the rate they are credited?
11. How are the benefits of RECs/SRECs distributed among project developers and subscribers?
12. Can you describe the application process for a potential subscriber? **(if applicable)**

19a. Is there a credit check?
19b. Is there a sign-up fee or on-going fee?
19c. What is the contract length? Early termination fee?
19d. Transfer options?

13. Are there services available for potential subscribers to navigate the application process?
14. Approximately what percentage of your total project kW is residential vs commercial or Who is your biggest customer?
15. Does the project ensure a certain percentage of subscriptions is allocated to different stakeholders? If yes, is this mandated by state policy?
16. Approximately what percentage of your total project is subscribed by lower-income households?
17. From the perspective of your organization, should Community Solar policies have a focus on low-income households? Why or why not?
18. How affordable are Community Solar projects for lower-income households?
19. Does your organization receive any benefits for lower-income subscribers?
20. Does your organization have any partnerships with low-income housing facilities?
21. Any other information you would like to share?

Interview protocol for state government agency:

1. What are the legislative goals of Community Solar policy (*enter bill name*)?

2. Are the current Community Solar projects meeting these goals?
3. What are the benefits of Community Solar? (for subscribers, developer, and utility)
4. Why does the policy include/does not include low-income carveout?
5. How is the compensation scheme for subscribers designed? (Net metering, virtual net-metering, vs value of solar).
6. Why was this compensation scheme selected over other options?
7. Who maintains the ownership of RECs and are these benefits shared with subscribers?
8. How do CS programs benefit lower-income households?
9. What kind of incentives does CS provide for lower-income households to participate?
10. Does the state require utilities to procure a certain percentage of their total load through renewable energy? If so, how do you anticipate CS to contribute to this target?
11. From your perspective, do potential subscribers have access to adequate information?
12. Are there services available for developers and subscribers who are having difficulty with their respective application process?
13. What incentives or rebates are available for project developers in order to finance a project?
14. Have utilities experienced any challenges in incorporating CS programs?
15. Should projects allocate the mandated minimum subscriptions for lower-income households or strive to accommodate to more low-income households beyond the minimum requirement? (**for states that have low-income provision**)
16. Any other information you would like to share?

Interview protocol for CS developer:

1. Would you please describe your organization's involvement with CS? Which states does your org operate in?
2. What are the goals of CS for your organization?
3. What are the benefits of CS for your organization?
4. What is the motivation for your organizaiton to build Community Solar projects? Role of incentives?
5. Did your organization experience project siting challenges (such as community resistance)?
6. How long did the developer application process take?
7. Was the application process easy to navigate?
8. Did your organization experience any unexpected barriers that were not accounted for during project development and/or operation?
9. Did your organization experience any financing challenges during project development?
10. Has your organization experienced other economic challenges such as high taxes and lack of incentives?
11. What incentives or rebates was your organization able to utilize in order to finance the project?
12. What kind of support did your organization receive from state and federal agencies?
13. Would you say this support was adequate? Why or why not?
14. Did your organization experience or currently experiencing any difficulties with state or federal regulation compliance? If yes, what kind?
15. What strategies does your organization use to recruit subscribers? (marketing, campaigns, community outreach/engagement?)
16. Does your organization have outreach and marketing material that specifically targets LMI households? If yes, what aspects does this material highlight?

17. What incentives are there for subscribers to participate in the project?
18. How does your organization communicate these incentives?
19. Can you describe the application process for a potential subscriber?
    - Is there a credit check?
    - Is there a sign-up fee or on-going fee?
    - What is the contract length? Early termination fee?
    - Transfer options?
20. Are there services available for potential subscribers to navigate the application process?
21. Has the program experienced any challenges with subscriber enrollment/program marketing?
22. What percentage of your total project kW is residential vs commercial?
23. Approximately what percentage of your total project is subscribed by lower-income households?
24. Does the project ensure a certain percentage of subscriptions is allocated to different stakeholders? If yes, is this mandated by state policy?
25. Does your program have any participation restrictions?
26. Does your organization receive any benefits for lower-income subscribers?
27. Does your organization have any partnerships with low-income housing facilities?
28. Any other information you would like to share?

Interview protocol for nonprofits:

1. Can you please describe the work of your organization regarding Community Solar?
2. From the perspective of your organization, what would you say are the goals of Community Solar policy for your state?
3. Would you say that the current policy is accomplishing these goals?
4. Would you say that the costs and benefits of Community Solar in your state are distributed equitable or fairly?
5. Who would you say is benefitting from the CS Program in your state? (households, or businesses & commercial entities)
6. How successful would you say Community Solar in your state has been in giving solar access to lower-income households?
7. What challenges does your organization see lower-income households experiencing/might experience that prevent them from enrolling in CS?
8. How aware are low-income households about energy options available to them?
9. How affordable are Community Solar projects for lower-income households?
10. Does your organization think CS policies should have a focus on lower-income households such as an incentive structure to include low-income? Why or why not?
11. In what ways do you think the CS policy could be reformed?
12. Any other information you would like to share?