

## The Political Economy of Community Solar: Lessons from Minnesota

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### Abstract

Solar energy is rapidly growing in the United States due to declining costs and favorable policy incentives at the national, state, and local levels. However, many household and business electricity consumers do not have access to solar energy due to a lack of appropriate or available rooftop space and financing constraints. To broaden access to solar energy, fifteen states (and the District of Columbia) along with an increasing number of electric utilities, have developed policies to incentivize community solar programs. Traditionally, solar energy requires either centralized planning for large, utility-scale project development or for customers to own or finance single solar projects located on their own property. In contrast to traditional models, new community solar programs allow multiple electricity consumers, often in close geographic proximity, to collectively finance a single offsite centralized solar project by purchasing shares or subscriptions to power generated by the project. Participants who finance the development of a community solar project receive bill credit for electricity generated by their share in the project.

Minnesota has long been on the forefront of community solar. In the early 2010s, several of Minnesota's electric cooperatives and municipal utilities adopted community solar programs. In this paper, we study the diversity in community solar program design and its effects on accessing the benefits of community. Our study helps illustrate how the implementation of community solar programs affects performance, offers lessons to better anticipate the potential downfalls in program design, and identify best practices to enhance equitable access to the market for solar energy.

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## 1. Introduction

The challenges associated with broadening access to technology in the transition to sustainability is a growing area of scholarship (Anadon et al., 2016). Within this field, the rapid deployment of solar energy is seen as a key strategy to mitigate climate change and reduce other environmental impacts of energy use (IEA, 2016). In the United States, solar energy adoption is growing rapidly, but as of 2015, solar comprised less than 1% of national electricity generation (EIA, 2017). Solar energy's growth is also constrained; in the United States, half of residential and commercial electricity consumers lack the onsite space to install solar panels (Feldman et al., 2015). Even fewer consumers can support the high upfront finance requirements of solar, despite declining costs and favorable national, state, and local policies (Asmus, 2008).

## 2. Community Solar

Innovation in “finance and business solutions to expand access to capital” is a major focus of public policies to address the non-hardware costs<sup>1</sup> of installing solar power (U.S. Department of Energy, n.d.). One promising approach to addressing solar energy's financing challenges are community solar programs, now adopted in 15 states (and the District of Columbia), along with an increasing number of electric utilities. Traditionally, solar energy requires either centralized planning for large, utility-scale project development or for customers to own or finance single solar projects located on their own property. In contrast to traditional models, new community solar programs allow multiple electricity consumers, often in close geographic proximity, to collectively finance a single offsite centralized solar project by purchasing shares or subscriptions to power generated by the project. Participants who finance the development of a community solar project receive bill credit for electricity generated by their share in the project. By expanding the market in this way, community solar programs potentially double the number of customers who can access solar energy (Feldman et al., 2015).

Community solar programs offer several streams of potential benefits. First, community solar projects can lower average costs of solar energy by capturing economies of scale relative to rooftop installations. Second, because they pool together many consumers, community solar programs are amenable to affordable finance models (Funkhouser et al., 2015; Interstate Renewable Energy Council, 2016a), thereby creating the potential to address existing inequities in the energy system (Granqvist and Grover, 2016; Rule, 2014). Finally, community solar programs may provide unique opportunities for community-level mobilization of resources (Walker et al., 2007), which could enable niche-level technology adoption as part of a larger-scale energy transition (Geels, 2002).

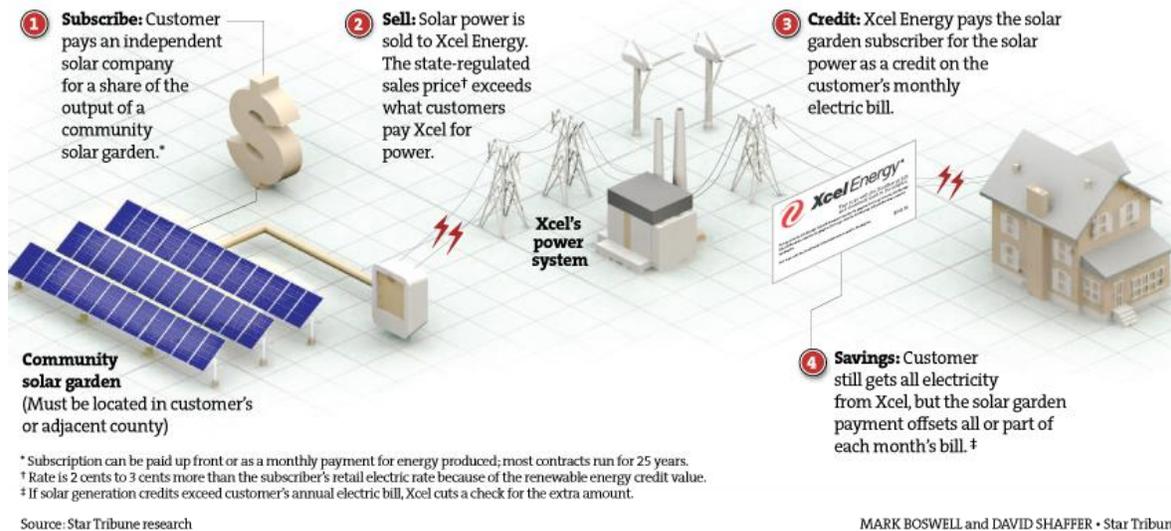
Increasing public resources at the federal and state level are being dedicated to accelerating these programs (U.S. Department of Energy, n.d.). As a relatively new area of practice, community solar programs have been studied in only very limited fashion in the scholarly literature (Chang et al., 2017; Funkhouser et al., 2015). As states and businesses consider adopting or reforming community solar programs, it is critical to build on the experience of the 15 states (and even more utilities) who have been early adopters. Yet no two community solar programs are identical (Coalition for Community Solar Access, 2016; Interstate Renewable Energy Council, 2016b). It is likely that how these programs are designed and implemented impact the pace and scale of community solar development as well as the fairness of how energy consumers participate.

As states continue to grapple with how best to deploy solar to maximize clean energy growth, and overcome the high upfront costs inherent in renewable energy development, community solar has emerged as a promising alternative financing model. In contrast to traditional models, community solar programs allow multiple electricity consumers, often in close geographic proximity, to collectively finance a single offsite centralized solar project by purchasing shares or subscriptions to power generated by the project. Participants who finance the

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<sup>1</sup> The U.S. Department of Energy estimates that the non-hardware costs, or “soft” costs, comprise 64% of the total installation cost of a new solar power system (U.S. Department of Energy, n.d.).

development of a community solar project receive bill credit for electricity generated by their share in the project (Chwastyk and Sterling, 2015; National Renewable Energy Laboratory, 2014).



**Figure 1.** Schematic of arrangements between solar garden developers, solar garden subscribers, and the electric utility in Minnesota's community solar garden program in Xcel Energy's territory. Reproduced from Schaffer, 2015 (Schaffer, 2015).

## 2.1. The rationale for community solar

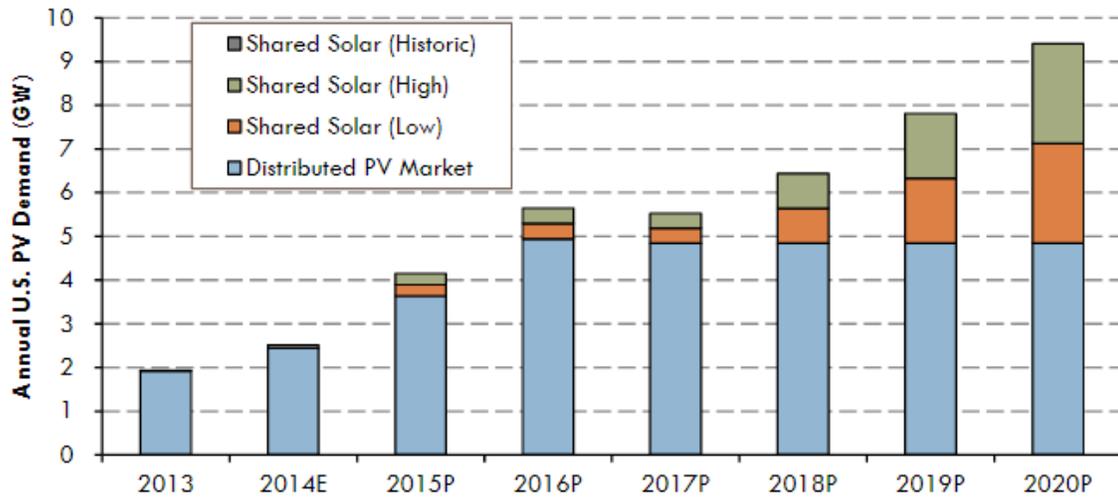
Community solar program design can vary significantly across states and electric utilities, but are generally supported for their potential to increase the rate of solar deployment and make the opportunity to finance solar energy more affordable and accessible (Chwastyk and Sterling, 2015; National Renewable Energy Laboratory, 2014). Community solar projects can lower average costs of solar energy by capturing economies of scale relative to rooftop installations (National Renewable Energy Laboratory, 2014). Second, because they pool together many consumers, community solar programs are amenable to affordable finance models, thereby creating the potential to address existing inequities in the energy system for customers who are prevented from having their own systems due to lack of credit (Funkhouser et al., 2015; National Renewable Energy Laboratory, 2014; Stanton and Kline, 2016). Finally, community solar programs may provide unique opportunities for community-level mobilization of resources (Schroeder McConnell et al., 2016), which could enable niche-level technology adoption as part of a larger-scale energy transition (Geels and Schot, 2010).

One major benefit to community solar programs for consumers is that it increases access of solar energy for customers who do not have appropriate rooftop space or could not otherwise benefit from residential distributed solar generation (Chwastyk and Sterling, 2015; Funkhouser et al., 2015; National Renewable Energy Laboratory, 2014). If the program is designed with consumer incentives like fixed solar rates, shared investment returns, or per unit bill credits that are greater than the per unit cost of the community solar subscription customers are paid over time rather than paying a premium for solar energy (Funkhouser et al., 2015; Stanton and Kline, 2016). This can stabilize the rate the customer pays for electricity while offering potential bill savings (National Renewable Energy Laboratory, 2014).

For a utility, increased residential solar penetration threatens to disrupt the traditional utility-customer relationship. Community solar on the other hand has the potential to improve the utility-customer relationship, and give the utility more control over new distributed generation projects (Chwastyk and Sterling, 2015; Funkhouser et al., 2015; National Renewable Energy Laboratory, 2014; Stanton and Kline, 2016). Improved relationships come with the added benefit that demand continues to pass through the utility when the CSGs are utility owned, thus stabilizing revenues. Depending on the state, utilities may also benefit from being able to retire

RECs generated from community solar projects towards a RPS (National Renewable Energy Laboratory, 2014). However, these benefits vary by utility type and severely diminish under third-party led community solar garden programs. These “special purpose entity” designed programs are typical only in partnerships with investor owned utilities (IOUs) (Funkhouser et al., 2015). Utilities may also encounter greater financial burden dealing with the billing mechanism (Chwastyk and Sterling, 2015).

In general, community solar programs aim to achieve two related objectives: (a) increasing the overall level of solar energy deployment, and (b) broadening who has access to the benefits of adopting solar energy (Chwastyk and Sterling, 2015; Funkhouser et al., 2015). However, given the flexibility of program design options and ensuing variety, not all programs have delivered on their potential and it is likely that how these programs are designed and implemented impact the pace and scale of community solar development as well as the characteristics of the consumers that participate. For this reason, it is important to take into consideration different contexts, design elements, and policy barriers to creating an effective community solar program.



**Figure 2.** Estimated technical potential of community solar (National Renewable Energy Laboratory, 2014).

## 2.2. Community solar program design

Much of the current literature classifies the most important differences in program design across the many community solar projects and utility types. When programs are designed by a state legislature each state program defines who are the participants, what the customer reimbursement will be, subscription terms, and other program limits (Trabish, 2017). Therefore, it is pertinent to take into account the different program design options while evaluating community solar programs.

The Solar Electric Power Association (SEPA) highlights the twelve different design decisions a program must take into account: customer offer, economic proposition, one-time sign-up fee, REC treatment, siting and scale, usage participation limit, capacity participation limit, production guarantees, minimum terms, program length, subscription transfers, and what to do with the unsubscribed energy (Chwastyk and Sterling, 2015). A recent Princeton report reiterates many of these characteristics but simplifies the list into nine distinct topics: (1) Rate Design, (2) Financing, (3) Grid Integration, (4) Siting and Permitting, (Timilsina et al., 2012) Project Size and Capacity, (6) Subscription Structure, (7) Developer Application Process, (8) Community Engagement and Education, and (9) Ensuring Widespread Access (Chang et al., 2017). The last category recognizes the possibility of facilitating LMI subscriber participation in shared solar projects as in the case of Colorado’s program statute (National Renewable Energy Laboratory, 2014; Stanton and Kline, 2016). Lastly, an increasingly important

design consideration is consumer protections, education, and disclosure. These provisions help potential subscribers acquire all of the facts necessary to weigh their options effectively (Stanton and Kline, 2016).

Rate design and the customer offer are arguably the most essential aspects of designing an effective community solar program. Many of the financial benefits to consumers outlined above, and the incentives for developers in third-party led utility programs stem from having a rate that credits subscribers appropriately for their share of the electricity. The rate the subscriber pays must be lower than the rate that they credited in order for the participant to benefit in the form of bill savings (Stanton and Kline, 2016). The most common ways of crediting community solar are virtual net metering and value of solar (Chang et al., 2017; Funkhouser et al., 2015; National Renewable Energy Laboratory, 2014). A stable and appropriately drafted bill credit rate and transparency of development can also lower the financial risk that financiers may see with community solar by increasing the predictability of returns (Chang et al., 2017).

The choice of ownership and price to participate can also dramatically affect participation in community solar programs. What SEPA refers to as “economic decisions” deal with whether the customer must pay for their subscription up front or overtime, whether there is a bill credit or line item (on bill) payment, and if there is a refundable down payment to sign up or not (Chwastyk and Sterling, 2015). If the up-front financing costs are too high, or the relationship between monthly payments and expected monthly credits is not balanced correctly LMI customers may find it particularly difficult to purchase a share of a community solar garden (Stanton and Kline, 2016). For these reasons, pay as you go has been viewed by some developers as easier to set up since it is easier to get customers relative to paying up-front (Trabish, 2017).

Other design features that are considered are cap on total program size, and the amount of capacity or percentage of a solar project that an individual subscriber can purchase or subscribe to (Chwastyk and Sterling, 2015; National Renewable Energy Laboratory, 2014). SEPA discusses participation limits in terms of usage and capacity limits that have been implemented to ensure that multiple subscribers can benefit from one community solar project. Usage limits cap subscription levels to a given percent of a customer’s average annual power usage, and range from 50% to 120%. Capacity limits on the other hand restrict the total number of panels that a single subscriber can purchase (Chwastyk and Sterling, 2015). Both forms of participation restrictions attempt to ensure that one subscriber who uses a lot of power, like a large company, cannot subscribe to the entirety of a project.

A final aspect of community solar program design that has garnered much attention in the literature is the uncertainty of interconnection and customer acquisition. The relative opaqueness, cost, and length of the siting and interconnection process can increase the uncertainty for developers and financiers, and slow the speed of program rollout. States that have caps on net metering project sizes in addition to limits on how much energy production can be credited also, “increase the risk and may slow or halt solar project development”, if developers are uncertain about whether or not their development will qualify (National Renewable Energy Laboratory, 2014).

In terms of customer acquisition, reports have pointed to a tradeoff between the number of subscribers needed to fully subscribe a shared solar project and risk of under subscription (Chwastyk and Sterling, 2015). In order to counter some of this risk many programs, especially in immature markets, have opted for contract lengths between 20 and 25 years, despite customer preferences being between 5 and 10 years (Chwastyk and Sterling, 2015; Stanton and Kline, 2016; Trabish, 2017). Customers may balk at such long commitments if appropriate and easy transfer options are not in place.

Even if every aspect of program design is considered in the creation or evaluation of a community solar program, one must recognize that each of the decisions, “is made within the context of the greater regulatory and utility regime, and can affect one another” (Chwastyk and Sterling, 2015).

### **2.3. The utility context for community solar**

Variety in program design presents additional challenges when trying to create cross-program comparisons between community solar models. Typically, one could examine if the array is, “fully subscribed, if the program returns value to all ratepayers in an economically balanced and equitable manner, and if the subscribers are satisfied with the program” (Chwastyk and Sterling, 2015). However, program designers must also take into account the utility structure in every context where community solar operates. Community solar is inherently flexible since it must operate within different utility-business models that attract different community solar models, and therefore offer different benefits to the utility and customer (Funkhouser et al., 2015; Trabish, 2017). The most common differentiation in the literature is between utility-led and third party-led programs (Coughlin et al., 2011).

In utility administered programs the utility is in charge of every aspect of community solar construction, interconnection, design (subject to constraints by the legislature), operation, and billing. These programs are more likely to occur in vertically integrated, regulated utilities than in deregulated states (Stanton and Kline, 2016). Smaller municipal utilities (MUNIs), and electric cooperatives generally begin their foray into community solar through programs of less than 500 kW, and contract out specific support services (billing, operations, maintenance) (Chwastyk and Sterling, 2015). In Minnesota, electric cooperatives were the early adopters of community solar, and offer a combination of up-front and pay-as-you-go payment options. Larger investor owned utilities (IOUs) may begin with a pilot program but generally have larger programs of over 20 MW (Chwastyk and Sterling, 2015). Finally, utility-led programs tend to use virtual net metering where the participant receives a credit for their portion of the solar project (Coughlin et al., 2011).

As already explored above, the benefits to utilities in utility-led programs are significant. The utility maintains control over the distributed generation project, demand continues to pass through the utility, RECs can be retired against the utility’s RPS where applicable, and the utility can improve relations with its ratepayers (Funkhouser et al., 2015; National Renewable Energy Laboratory, 2014). The utility would also qualify for rebates, incentives, and modified accelerated cost recovery to buy down the costs of developing the community solar project. These benefits could be indirectly passed on to participants since any participant would not qualify for many of the tax credits available (Coughlin et al., 2011).

In third party or special purpose entity (SPE) programs community solar project developers partner with utilities to develop, manage, and maintain the solar array, assigns kWh to utility accounts, or sells their electricity to the utility through a PPA (Chwastyk and Sterling, 2015; Coughlin et al., 2011). The utility is charged with facilitating the billing, interconnection, and management of the distribution system (Trabish, 2017). These programs proliferate in regulated states with larger IOUs and shared solar policies as in Colorado and Minnesota. Nonprofit third party community solar developments have also emerged where the project is wholly owned by the subscribers. Though few in number they have been successful in developing community solar models that include low and moderate income subscribers (Chwastyk and Sterling, 2015).

As opposed to utility-led programs, third party programs diminish the value to the utility that administers the program. The utility either signs a PPA with a special purpose entity, or works with a developer by administering the program (Chwastyk and Sterling, 2015; Coughlin et al., 2011). In both cases the utility does not own the solar array. This is an important consideration when creating a program given the extent to which the utility could resist such infringements into its territory by third party developers. Additional legislation may be required to facilitate such development (Stanton and Kline, 2016). Finally, third party-led programs may still qualify for rebates, incentives, and MACRS that can be retained by the developer, or once again passed onto participants indirectly (Coughlin et al., 2011).

#### **2.4. Access and equity in community solar**

At the center of community solar is access for those without an adequate roof or finances. The definitions of “access,” however, vary across jurisdictions. It can mean access to electricity where there wasn’t any before;

access to ownership of renewable energy credits; access to the opportunity of owning solar; and access to the financial benefits of owning solar.

There is also the issue of fairness, raised broadly, that low- to moderate-income (LMI) customers should have access to the shared financial benefits of building new renewable energy infrastructure (Hoffman and High-Pippert, n.d.). Research has found that median energy expenditures for low-income customers can account for more than five percent of income in many major metro regions across the United States (Drehobl and Ross, 2016). Other research has found that electricity expenditures account for 9.92 percent of income for the lowest quintile of earners (Sabol, 2016).

Community solar, in centralizing maintenance and finance to an offsite array, perceivably could mitigate risk and costs for LMI customers. Using different financing structures, hybridized contracts, and recruiting different subscriber types, community solar projects could spread financial risk more evenly among its subscribers (Schroeder McConnell et al., 2016).

Amid growing interest in LMI customers, organizations such as the Interstate Renewable Energy Council (IREC) have released policy recommendations to better include LMI customers in shared renewable energy projects, though there are relatively few concrete examples of programs that target LMI customers (Schroeder McConnell et al., 2016). IREC considers the importance of specificity in definitions of who LMI customers are and programmatic structures, what financing mechanisms they should have access to, and what percentage of total community solar garden capacity they should have subscription to.

Political power dynamics continue to play a role in community solar offerings, as the utility may seek us community to maintain a current utility-customer financial relationship and a predictable return for their investors, or a third-party may seek to weaken that same relationship (Funkhouser et al., 2015; Granqvist and Grover, 2016; Rule, 2014). Further erosion of the utility rate-base by customer self-supplying electricity has led to worries over the “utility death spiral,” where the utility collects less revenue, drives up rates, inducing more customers to self-supply their energy, thereby exacerbating the cycle.

Debates over the fairness and potential cross-subsidies of solar net metering programs have also spilled into community solar programs. Here, low-income customers are said to subsidize higher-income customers who have the money or means to buy solar panels. Yet as one study determined for one hypothetical Southwestern electric utility, federal subsidies for the low-income energy expenditures remain much higher than the potential rate impacts of solar at even 10 percent of demand, where net-metered solar was predicted to increase rates by only 2.5 percent (Rule, 2014).

Who pays for what can be determined through multiple perspectives of fairness, whether the payer for clean energy infrastructure be the polluter for his or her current pollution levels; the polluter for past and current pollution levels; the beneficiary of pollution; or simply those who have the most means to pay for pollution (Granqvist and Grover, 2016). In the electric grid where numerous cross-subsidies are incorporated to traditional rate structures, distributive fairness can be examined in added contexts of energy security and economic development.

In Minnesota’s community solar program, fairness is one of the main lenses in which the program was promoted (Hoffman and High-Pippert, n.d.). Xcel Energy, a regulated vertical monopoly, had little to no solar in its territory. Seeking to promote solar growth and a German-like energy transition, state legislators approved a community solar program in 2013 with reimbursement through the Applicable Retail Rate, similar to Germany’s feed-in tariff, which would over time transition to the Value of Solar rate, an avoided cost formula which adds in the environmental benefits of supply solar to the grid.

The program was intended to be small, but the high reimbursement rate combined with fuzzy program requirements led to an outpouring of applications for community solar gardens, more than 100-times the state’s previous solar capacity. Rather than being subscribed to by mostly residents and plotted mostly within

communities, most solar garden capacity remains taken up by large electricity users, and most solar gardens are built in the country, away from towns and cities, according to anecdotal and early evidence from the utilities commission.

Though adders to the Value of Solar rate are currently being considered for developers who recruit more residential or LMI customers, current willingness to incorporate LMI customers remains limited to a few developers who go beyond the minimum community solar program requirements.

## **2.5. Other interacting policy considerations**

Outside of program design considerations, the utility structure, and government incentives and rebates, the success of any community solar program has been found to depend on the interactions with the wider policy context in which it operates. One such important prerequisite policy already discussed is virtual net metering. Virtual net metering is the most common form of billing and reimbursing consumers for their share in a community solar project (Chang et al., 2017; Funkhouser et al., 2015; National Renewable Energy Laboratory, 2014). Unlike its cousin net energy metering, virtual net metering allows participants in shared solar programs to receive credit for their portion of off-site generation (National Renewable Energy Laboratory, 2014). Without this or a similar policy in place states that specify on-site generation only community solar garden subscribers would not be eligible to receive credit scaled by their portion of the energy. State net metering policy can also place caps on the total amount of energy that can be credited, creating uncertainty for community solar financiers, subscribers, and developers (National Renewable Energy Laboratory, 2014).

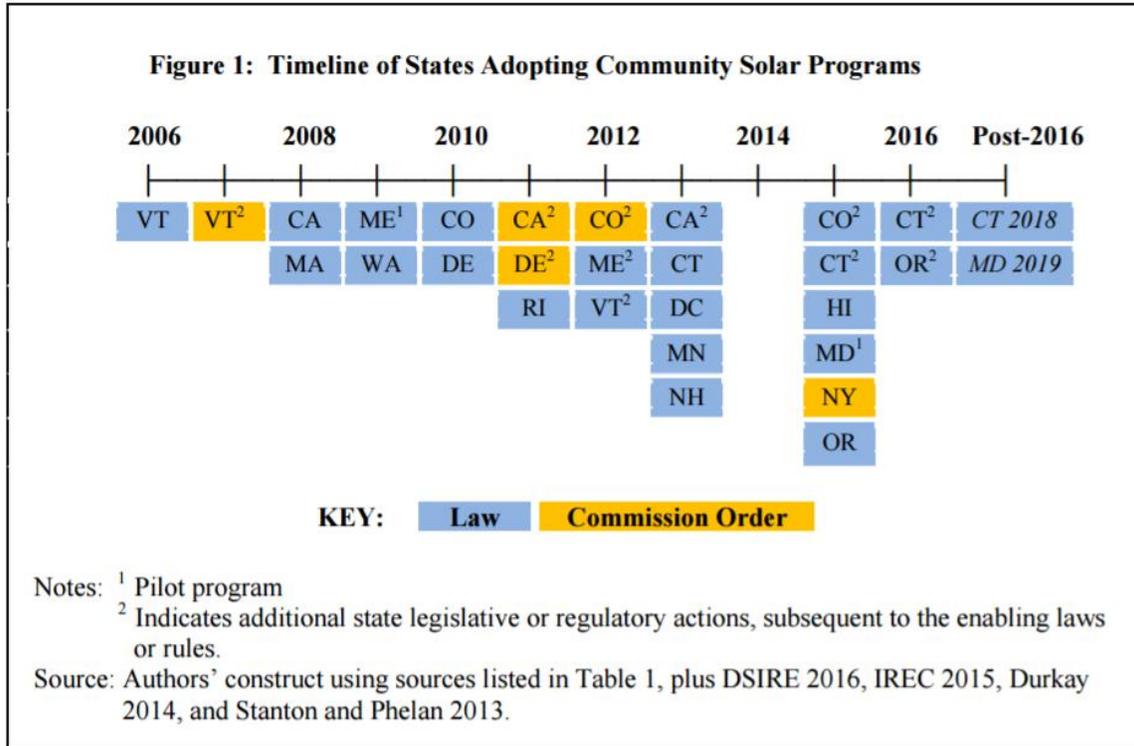
State and utility interconnection policies that are not overly complex or lengthy is another crucial policy interaction to consider. Interconnection is “the process by which distributed energy resources are connected to the electric grid” (Chang et al., 2017). National Renewable Energy Laboratory has emphasized that ensuring community solar program are not subject to lengthy, uncertain, and complex application and approval process can reduce risk and speed up roll out of community solar garden programs (National Renewable Energy Laboratory, 2014). Nowhere has this risk been more apparent than in Minnesota where the state’s main utility, Xcel Energy, was forced to conduct an independent review of its interconnection and engineering review process in the wake of mounting frustrations over slow program rollout (Denniston, 2016).

The last external policy interaction not yet reviewed is how community solar garden projects and program models fit in the current rules and regulations about financial securities promulgated by the Securities and Exchange Commission (SEC). A security is a stock, note, or investment contract, and in the past the SEC has issued a letter of no action to one model of community solar stating that it did not necessarily provide an expectation of profit (Feldman et al., 2015). A community solar project can submit a request to the SEC describing the business model being used and presenting the technical and legal analysis of why the host believes the business model is not a security (National Renewable Energy Laboratory, 2014). However, if deemed a security the project will require additional time and accrue more expenses to ensure compliance, and upfront costs that many projects could not support (Coughlin et al., 2011). On strategy suggested to avoid securities regulation it is suggested that capacity should not exceed the annual generation of the subscriber by more than 120% since it then may not be deemed an electric contract anymore since high overproduction and compensation allowances can undercut the argument that a system electricity generation is designed for personal use (Chwastyk and Sterling, 2015; Feldman et al., 2015). Another is to ensure that Marketing need to emphasize reducing a customer’s retail electricity bills over making a profit (Feldman et al., 2015).

## **2.6. Where is community solar today?**

Community solar has expanded significantly and there is now a community solar programs adopted in 15 states and the District of Columbia. Nine of the fifteen programs (Colorado, Delaware, DC, Illinois, Maryland, Massachusetts, New York, Rhode Island, and Vermont) were implemented in the context of existing net energy metering programs, while the rest (California, Connecticut, Hawaii, Maine, Minnesota, New Hampshire, Oregon,

and Washington) do not share explicit links between pre-existing net metering policies (Stanton and Kline, 2016). The vast majority (73%) of the community solar projects in operation offered only upfront payments, while 17% offered ongoing payments in 2015. In terms of customer payment options, 71% offered bill credits while 29% provided separate line-item payments (Chwastyk and Sterling, 2015). Most of the community solar programs created by state legislation establish maximum total community solar capacity limits, maximum capacity limits for each participating project, minimum numbers of participants in each project, maximum amount of energy to be generated per participant, and location requirements (Stanton and Kline, 2016).



**Figure 3.** History of community solar legislation adoption by states (Stanton and Kline, 2016).

### 3. Community Solar in Minnesota

Minnesota has long been on the forefront of community solar. But its program for the state’s largest utility has gone through several reforms that have created uncertainty and slowed development. Still, with over 50 megawatts operating by the end of 2016, Minnesota has one of the country’s largest community solar programs in the country. Beginning with programs in Minnesota, this paper seeks to fill the gap in understanding in how community solar program design impacts who can access solar energy and the pace and magnitude of new solar development.

Co-ops and municipal solar programs in Minnesota adopted community solar models in the early 2010s. Inspired by the success of this program in other Minnesota utilities, and across the country, the Minnesota legislature ordered the regulated utility Xcel Energy to implement a community solar program in 2013. This program drew initial applications for over 1.7 gigawatts of photovoltaic capacity, equivalent to more than 100-times the current annual solar installation in the state. Today, Xcel Energy’s community solar program in Minnesota is one of the largest in the country. More information on Xcel’s Minnesota community solar program can be found in the Appendix.

### 4. Studying Equity in Community Solar

Community solar programs aim to achieve two related objectives: (a) increase the overall level of solar energy deployment, and (b) broaden access to the benefits of adopting solar energy (Feldman et al., 2015). This project will adopt these two goals as the central dimensions of analysis.

In summary, we propose to assess the following compound hypothesis for the Minnesota community solar program:

Community solar programs have increased the overall level of solar deployment. However, this increase is primarily due to favorable financial incentives for project developers. These policies have created financial benefits for community solar subscribers, but these subscribers are primarily in the highest income brackets due to restrictive barriers to subscription access. The control of renewable energy assets in community solar projects resides primarily with large electric utilities that use community solar to achieve a wider array of objectives.

Testing aspects of this hypothesis across the utility territories in Minnesota (and then expanding to other states with community solar programs) will allow us to compare the validity of the aspects of this hypothesis in relation to elements of program design to identify best practices.

## **5. Cross-subsidization to support community solar in Minnesota co-ops**

In this section, we present the methodology and results of the first part of our study to assess the degrees of cross-subsidization resulting from program design decisions in the Minnesota cooperative utilities that have developed community solar programs.

Over 15 cooperatively owned utilities (co-ops) in Minnesota have developed community solar programs. We collected project characteristics and subscriptions offers for each of the co-op community solar programs. Project characteristics included total project size and approximation for project costs based on National Renewable Energy Lab’s System Advisor Model (NREL, 2017). Subscription offer information includes subscription costs and terms (e.g. fixed, up-front charges and length of contract). We also collect current (residential) electricity rates for each co-op.

With this data, we calculate the degree of cross-subsidization between each co-op’s electricity customers to support the costs of community solar development. In general, cross-subsidization is a major concern throughout utility-side investments – not just in electricity, but in principle for all forms of large public infrastructure (Faulhaber, 1975). In electricity, rate cases regularly discuss concerns about cross-subsidization and other forms of cost pass-through.

Community solar gardens represent a particular kind of utility-side investment. This is because benefits/costs accrue to two types of demand-side actors: subscribers and nonsubscribers. Understanding of cross-subsidization is also complicated by the presence of two supply-side actors: utilities and solar developers/owners.

What follows is an analytic frame for understanding cross-subsidization in the context of community solar garden investment.

### **5.1. Variable Definitions**

The variables used to investigate cross-subsidization are defined in the table below:

Name	Unit	Definition
lcoe	\$/kWh	Levelized cost of electricity: the net present value of investment, O&M, and other costs for a community solar garden project normalized by the total output of the garden. We use the Systems Advisory Model to estimate these values.  Note that lcoe should be inclusive of all subsidies (including the federal investment tax credit and Made in Minnesota, if applicable). Subsidies are cross-subsidized by taxpayers (federal and state) and are not part of the present cross-subsidization analysis, which is only considering cross-subsidization among utility ratepayers.
cf_rate	\$/kWh	Counterfactual rate: the counterfactual rate that a utility’s rate payer would pay inclusive of all fees and other per-unit charges (similar to the retail rate, but defined in this way to represent the lost revenue by a customer becoming a subscriber from a utility’s perspective).
add_solar	\$/kWh	Additional cost of solar: the cost of solar (inclusive of all costs in the lcoe) relative to the counterfactual rate less subsidies to solar
sub_rev	\$	Subscription Revenue: the total revenue collected from subscribers by a solar garden
gen	kWh	Generation: total electricity generation by a solar garden
add_con	\$/kWh	Additional cost of subscription contract: the implied or real terms in a solar garden subscription contract in terms of the per-kWh subsidy or cost to the subscriber relative to the counterfactual rate that subscriber would otherwise be paying
cross_sub	\$	Cross subsidization: the total revenue generated from non-solar garden subscribers to service the cost of solar gardens net of subscription
grid_cost	\$/kWh	Grid costs: the total costs (or negative costs) on a per-kWh basis for the ancillary services provided by a solar garden
tariff	\$/kWh	Tariff: the amount on a per-kWh basis that a utility pays a solar developer for electricity generated by the garden. With virtual net metering, this is typically a constant value for each unit of electricity generated. In Minnesota, this had been the ARR and moved to the VOS in January 2017.
sub_markup	\$/kWh	Subscription markup: the additional cost per unit of electricity generated by a CSG to service a CSG’s operational costs (e.g. cost of customer acquisition, subscription administration, marketing, etc.)

### 5.2. Initial Relationships

First, the definition of add\_solar is found by the difference of lcoe and the cf\_rate, which can be identified as follows:

$$lcoe = cf\_rate + add\_solar_1$$

This relationship is an identity that shows that the levelized cost of solar (less subsidies) is equal to the counterfactual rate plus the additional cost of solar (by definition).

In practice,  $add\_solar$  may be more usefully calculated by separating out  $grid\_cost$ , changing this identity so that the additional cost of solar is net of grid costs/benefits that are external to ratepayers and solar developers.

$$lcoe = cf\_rate + add\_solar + grid\_cost$$

Second, there is a relationship between subscription revenue and rates:

$$sub\_rev/gen = cf\_rate + add\_con$$

This relationship shows that the per-unit of generation revenue from subscriptions (from the point of view of developers) is equal to the per-unit revenue from electricity generation and the additional revenue from subscription contracts. There is an implicit assumption in here that the contract terms all have a built-in (virtual) net metering provision where electricity purchased (indirectly) through CSG subscriptions are virtually net metered by the utility.

Third, the  $cf\_rate$  has several sub components:

$$cf\_rate1 = wholesale\_rate$$

$$cf\_rate2 = wholesale\_rate + markup1$$

$$cf\_rate3 = wholesale\_rate + markup1 + markup2$$

$$cf\_rate4 = wholesale\_rate + markup1 + markup2 + markup3$$

This decomposition of the  $cf\_rate$  illustrates the complexity of rate design in electricity markets. Here the sequential markups represent: (1) the wholesale rate, (2) the average revenue rate ( $wholesale\_rate + markup1$ ), (3) the retail rate ( $wholesale\_rate + markup1 + markup2$ ), and (4) the retail rate net of fixed charges for renewable energy  $wholesale\_rate + markup1 + markup2 + markup3$ .

For the purposes of understanding the counterfactual rate for solar gardens, the relevant counterfactual is the one representing the revenue that a utility loses as a result of a utility customer becoming a CSG subscriber. In the presence of virtual net metering, the relevant counterfactual is  $cf\_rate3$ . The relevant counterfactual might change, if for example, one were to use the cross-subsidization analysis framework below for a utility-scale solar project (where power generation offsets electricity on the wholesale market).

Fourth, in principle, the tariffs paid to developers can be thought of as:

$$tariff = cf\_rate + sub\_rev / gen$$

This relationship implies that developers are able to fully pass through the difference between tariffs and the counterfactual rates to subscribers. In reality, there may be operational costs, so that more accurately, this relationship is:

$$tariff = cf\_rate + sub\_rev / gen + sub\_markup$$

$sub\_markup$  includes, but is not limited to, factors such as customer acquisition, subscription administration, and marketing costs.

### 5.3. Cross-Subsidization Analysis

With the assumption of zero profits, we can equate total costs and revenues in the system (from the perspective of the developer). This assumption is reasonable given the competitive environment in CSG subscription offers.

Total cost in the system is the sum of the solar garden project development and cost of servicing contracts.

Total revenue in the system is the sum of total electricity sales to subscribing customers (on the retail market) and cross-subsidization from nonsubscribers. This is expressed as follows:

$$\text{tariff} * \text{gen} + \text{grid\_costs} * \text{gen} = \text{cf\_rate} * \text{gen} + \text{cross\_sub}$$

Rearranging:

$$\text{cross\_sub} = \text{tariff} * \text{gen} + \text{grid\_costs} * \text{gen} - \text{cf\_rate} * \text{gen}$$

$$\text{cross\_sub} / \text{gen} = \text{tariff} + \text{grid\_costs} - \text{cf\_rate}$$

Substituting for tariff cancels cf\_rate:

$$\text{cross\_sub} / \text{gen} = \text{cf\_rate} + \text{sub\_rev} / \text{gen} + \text{sub\_markup} + \text{grid\_costs} - \text{cf\_rate}$$

$$\text{cross\_sub} / \text{gen} = \text{sub\_rev} / \text{gen} + \text{sub\_markup} + \text{grid\_costs}$$

This expression states that the revenue generated from non-subscribers per unit of electricity generated by a CSG is equal to the unit cost of generating electricity from the CSG plus the per-unit revenue from subscribers less the counterfactual rate that would have been paid for by subscribers.

This relationship shows that, all else equal, as subscription revenue increases (e.g. a CSG contract offers a 3 cent/kWh offer to subscribers instead of a 2 cent/kWh offer), the cross subsidization amount increases.

This relationship also shows that as project costs decrease (e.g. if solar gardens are built at larger scale with lower unit cost, the cross subsidization rate decreases).

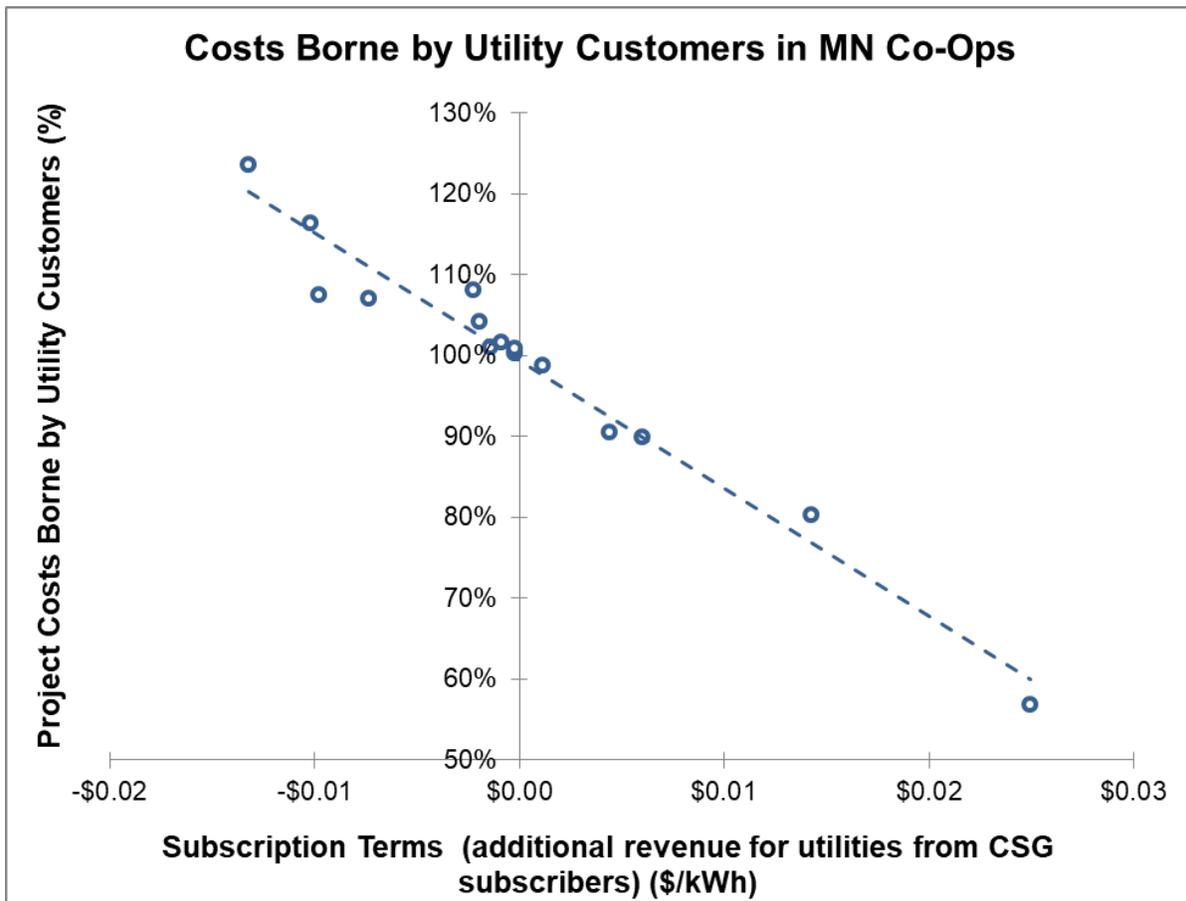
And finally, as the counterfactual rates that would have been paid for by subscribers goes down (e.g. if electricity prices decrease), then the cross subsidization rate increases (assuming tariffs to developers stay constant) because now a lower share of required costs to cover the project (and subscriptions) can be raised by the net metered electricity generation from the garden.

## 5.4. Results

The dependency between subscription contracts and cross-subsidization can be understood as the relationship between add\_con (the additional (per kWh) cost of subscription contracts, i.e. the per-kWh cost or benefit borne by subscribers) and the ratio of cross\_sub to total project cost (lcoe multiplied by gen). This ratio represents the percent of a community solar project's costs borne by non-subscribers.

Based on the derivations above, there should be an approximately linear relationship between the cost of subscription contracts and the cross-subsidization ratio. This would imply that as contracts become more favorable to subscribers, the costs imposed on non-subscribers increases. (Note that a utility-scale solar project financed and operated by the utility would have add\_con = 0 and a cross-subsidization ratio of 1).

Figure 4 shows the subscription terms and cross-subsidization ratios for 15 Minnesota co-ops with community solar programs.



**Figure 4.** The relationship between contract terms in a community solar program and the rate of cross-subsidization.

The average cross-subsidization rate across co-op CSG programs (weighted by project capacity) is 98%, meaning that the average community solar program shifts 2% less of the total cost of the project to non-subscribing ratepayers (as opposed to subscribers) for an equivalent solar development.

As expected, subscription contracts that pay subscribers as part of subscription contracts (left of the vertical axis) have cross-subsidization rates greater than 1. This implies that these contracts must actually raise more revenue from utility customers than required to finance the solar garden (utility customers must also raise the cost of paying subscribers). We find that the utility that imposes the greatest per-unit charges on its customers to support community solar has a 124% cross-subsidization ratio, meaning that the utility’s customers in principle would have their rates increased to cover 124% of the costs of the solar garden (in order to have to impact on utility profits).

Programs that charge subscribers fees for subscribing impose lower costs than a utility-operated solar project. Five of the 15 utilities studied have cross-subsidization rates less than 1. The program with the lowest cross-subsidization rate only must in principle raise rates on its customers to cover 57% of the project costs (in order to have to impact on utility profits). This suggests that the five community solar programs with cross-subsidization rates less than 1 have developed programs that shift financing costs onto subscribers and have thus lowered the rate impacts of deploying solar projects at this scale.

Greater degrees of cross-subsidization from utility ratepayers to cover the subscription benefits to community solar subscribers has equity implications. Based on anecdotal evidence, community solar subscribers tend to be wealthier than non-subscribers. This is because project developers selecting subscribers and marketing

subscriptions actively screen applicants to minimize risks associated with subscriber retention. From the utility's perspective, in a fluid, efficient community solar subscription market, there is little financial risk from offering subscription contracts. But because subscriber acquisition costs may be high, volatility in subscribers increases utility costs. Therefore, subscribers have developed criteria, such as credit score minimums, that limit access to community solar to only wealthy customers. Further, due to financing constraints in some (but not all) subscription contracts, subscribers may also be required to pay in cash or take out private loans, which also would limit access to subscribers to wealthier households.

## 6. Next steps

The next steps for this project will be to improve our understanding of the performance of community solar programs and how key performance metrics relate to the design decisions of community solar programs. Key metrics will assess the effectiveness of community solar programs in increasing total solar deployments levels as well as the equity in deriving benefits from community solar programs. These next steps will draw on a comparative approach across community solar programs in utilities within Minnesota and in other states.

The next steps of this project will rely on a combination of original datasets, publicly available datasets, privately shared proprietary datasets, and original case studies. This project will apply a variety of social science methods, both quantitative and qualitative. The primary methods will be economic and financial. We are developing financial cash flow models of both subscriber and solar developer decisions. These models will inform an economic search model of community solar adoption that is parameterized with the demographic and subscription data we are collecting. The basis for this model will be adoption decision models that have been used in the literature to assess residential rooftop solar adoption (Bollinger and Gillingham, 2012; Islam, 2014; Labay and Kinnear, 1981; Rai and Robinson, 2015; Wolske et al., 2017). This structure will allow us to assess the economic benefits of solar adoption under the various financing models available to subscribers and the empirical adoption factors that affect access to the benefits of the program.

We are taking several approaches to assessing the relationship between community solar program design and overall solar deployment. An econometric regression discontinuity approach will allow us to quantify how announcements of changes in the Minnesota program have affected developer applications for new community solar projects. We also plan to use a theoretical discrete choice model to identify the key determinants of the subscriber community solar adoption decision. These econometric approaches will help identify the impact of design changes in the Minnesota community solar program in Xcel Energy's territory on overall deployment levels.

We are also taking several approaches to assessing the second dimension: the relationship between community solar program design and access to benefits. First, we will assess the distribution of economic benefits through financial cash-flow models of community solar project developers and household subscribers. We plan to parameterize these models with the data collected on subscription contracts and demographic data. This would allow for a quantification of overall economic benefits as well as economic benefits by income groups. A critical piece of this analysis is to understand the overall rate impacts of mandated tariffs paid to community solar programs – we will quantify rate impacts by building on the large literature that has examined this question in the context of traditional energy capital investments (Joskow, 1998). A major concern underlying this part of the analysis is that despite increasingly favorable economics of community solar subscriptions, factors associated with lower income levels (particularly liquidity constraints, limited access to credit, and information barriers) regressively bias the distribution of benefits created by community solar programs. Second, we will assess the decision-making power of individuals and communities. We plan to quantify this dimension by studying cross-subsidization rates, renewable energy credit markets and asset control patterns. Interviews with stakeholders will help operationalize this dimension qualitatively and will help inform a power analysis of how community solar projects are designed, developed, and operated.

# Appendix

This appendix is a primer on the energy policy context of community solar programs. We review the literature on electricity policy, solar energy economics, solar energy finance, the adoption of solar energy, equity in access to solar energy, and community solar programs.

## 1. Electricity Policy Primer

In the United States, power production and distribution are separated. Energy is produced by regulated monopolies, which have been broken up by the introduction of co-ops and municipal power grids. Most states have a public utilities commission (PUC) which regulates the generation and distribution of power. Within these states, utilities may be regulated or deregulated. A regulated utility controls a vertically-integrated power system, from the plants that produce the power to the meter on a subscriber's property. Deregulated utilities only control the system to which other entities interconnect power generation, and which delivers power to subscribers.

Electrification benefits the economy and health of a state's citizens, but requires responsible management to regulate its production and distribution. In recent decades, promoting renewable energy in contrast to more traditional methods has become a goal of policymakers across America and the world. The methods used by each institution vary based on the resources and needs of the region, as well as political opinions about the relevance of climate science and the health effects of pollutants. Policy tools discussed in this paper will fall into the general categories of mandated generation capacities which force utilities to modernize their resources, and price mechanisms that use market tools to encourage utilities to change their methods of production.

Generating electricity requires high upfront costs with paybacks expected over years or decades. For example, solar panel arrays require materials and personnel for construction, but once they are established the costs of maintenance are minimal. To encourage utilities and developers to create new power generation facilities, policymakers have implemented finance mechanisms that incentivize development. Examples of these financing mechanisms include net metering and investment tax credits.

### 1.1. Policies to incentivize renewable electricity

Production tax credits (PTCs) reimburse production facilities that generate renewable energy by providing them with tax credits per unit energy produced. In America, this tax credit provided \$0.015/kWh in 1993 dollars to wind-powered facilities, and half that amount to solar and other renewable facilities, for their first ten years of operation (Department of Energy, n.d.). This benefit only applied to solar facilities that went online before 2016, and is no longer offered (Department of Energy, n.d.).

Investment tax credits (ITCs) are designed to offset the high upfront costs of renewable energy. The United States government offers a tax credit equal to 30% of the expenditures on equipment that uses solar energy to generate electricity (Department of Energy, n.d.). This credit will decrease starting in 2020, diminishing to 10% by 2022 (Department of Energy, n.d.). In America, ITCs are paired with depreciation deductions, which allows them to recover the cost inflicted by the reduction in value of the property over time. The major downside of ITCs is lost revenue for the governments that implement them (Timilsina et al., 2012).

The Public Utility Regulatory Policies Act of 1978 (PURPA) mandates that utilities purchase power from qualifying facilities, including small production facilities (Federal Energy Regulatory Commission, 2016a). To qualify, a small facility must produce less than 80MW of power through renewable means. PURPA is the law that first recognized the right of non-utility entities to own the means of power production, and in doing so broadened the marketplace. Under PURPA, non-utility entities that can produce power at a lower price than the utility can produce it are guaranteed to have the power purchased at "avoided cost," or the cost of generating the power in-house at the utility (Federal Energy Regulatory Commission, 2016b).

PURPA led directly to the implementation of net metering (defined below), which is a process through which households and businesses can be reimbursed for the power they generate on their property. Prior to PURPA, there was no federally-mandated policy saying that utilities needed to purchase or interconnect this power.

Most states have implemented policies that promote renewable energy. The subset of these policy options relevant in the Minnesota context are discussed below.

A renewable energy portfolio standard (RPS) is imposed when electricity suppliers are mandated to have a certain percentage of their electricity supply coming from renewable energy sources (Timilsina et al., 2012). These standards establish a trading regime such that companies which do not meet their burden of renewable capacity may purchase from those with renewable energy production above the mandated value. Some states, like New Jersey in 2010, have indicated that within their state's overall renewable portfolio, a particular fraction must come from solar power (Timilsina et al., 2012). A 2007 law sets Minnesota's RPS goal at 25% renewable energy production by 2025, and a 2013 law mandated 1.5% solar in Minnesota by 2020 and 10% by 2030 (Department of Energy, n.d.).

A feed-in tariff (FiT) is a premium or tariff or payment added to the cost of new or renewable electricity production which may not be competitive with the price of conventional generation (Timilsina et al., 2012). As of early 2010, this policy was in use by nations on five continents to ensure that more expensive technologies still produce a profit for the producer, and to signal to investors that long-term investment in these new products would be supported by user purchasing (Timilsina et al., 2012). A 2008 report by the Commission of the European Communities found that FiT is the most effective policy instrument to promote solar, wind, and biogas technologies (Timilsina et al., 2012). Finally, a FiT implemented without consideration of the interconnection costs for new solar plants could increase transmission costs across the market by forcing the grid to adjust the way it manages power (Timilsina et al., 2012). FiTs are often designed to fluctuate with the market, but this changing payment level can risk uncertainty changing payment levels can increase uncertainties for investors and increase overall market risk (Timilsina et al., 2012).

For all their benefits, a FiT cannot subsidize the high upfront cost of installing technology like solar power; as a result, it tends to drive electricity rates upwards for all consumers in the short term, in order to cover the cost of constructing the solar facility (Timilsina et al., 2012). Examples from Taiwan show that external factors like the upfront cost of installing solar, or limited space availability, can reduce the impact of FiT sponsorship for small-scale (0-10kW) solar (Couture et al., 2015).

Net metering allows households and commercial establishments to sell the excess power generated via rooftop solar or industrial processes back to the grid (Timilsina et al., 2012). This kind of metering pays the subscriber for their power at the same retail tariff for which they would otherwise purchase power from the grid (Timilsina et al., 2012).

## **1.2. Data privacy and the electricity sector**

The electric utility industry has historically been a data-driven enterprise, and increasing competition within the market has driven utilities to classify as trade secrets information that they might previously have shared (Vine, 1997). Investor-owned utilities in particular see customer-related information, including energy efficiency and avoided capacity costs, as a corporate asset (Vine, 1997). This imbalance of information can limit market competition, offset the regulatory balance between utilities and public utility commissions, and limit the ability of policymakers to make plans that reflect the current state of the energy industry (Vine, 1997). In general, commissions will allow utilities to classify consumer data if disclosure would not aid the public interest, or would harm the utility, or if the commission is working under too heavy an administrative burden (Vine, 1997).

In December, 2016, Minnesota's Public Utilities Commission (MNPU) received a briefing on the discussion of Consumer Energy Use Data (CEUD), in which some parties advocated for increased access to better benchmark

energy use, and others argued in favor of protecting consumers' privacy (O'Grady, 2016). Among the problems considered by the discussion, the panel considered how an individual might gain access to their own CEUD, and what aggregation rule would be appropriate for a group of people, such that no individual's power consumption patterns could be inferred from the averaged data (O'Grady, 2016). Since this discussion, MNPUC has been engaged in the process of defining a consent form for consumers to release their CEUD to outside entities (MN Docket 12-1344).

## **2. Economics of Solar Energy**

A limited number of consumers can support the high upfront finance requirements of solar, despite declining costs and favorable national, state, and local policies (Asmus, 2008).

### **2.1. Solar energy costs and benefits**

Historically, solar energy module costs (the costs of the actual solar panels) have declined faster than nearly any other energy technology (Nemet, 2006). However, the U.S. Department of Energy estimates that the non-hardware costs, or "soft" costs, comprise 64% of the total installation cost of a new solar power system (U.S. Department of Energy, n.d.). Module costs have declined faster than balance-of-system costs, and prices of installed solar systems still vary widely – by one estimate, U.S. solar system prices span more than a factor of four (Nemet et al., 2017). While prices of solar have declined, simultaneously, financial incentives have been adopted by many states and countries, and in many places where solar is adopted, the net present value of installing solar, once accounting for incentives, is positive (Borenstein, 2015).

Absent policies, however, the net present value of solar relative to efficient natural gas generation may actually be negative in many places, including sunny California (Borenstein, 2015). Lowering the costs of solar energy to be cost competitive may require further innovation (Schmalensee, 2015). One consideration in assessing the private costs of solar adoption is the rate of pass-through of financial incentives for solar adoption. Estimates of pass-through vary considerably, from less than 20% to nearly 100% (Borenstein, 2015; Dong et al., 2014; Henwood, 2014; Podolefsky, 2013).

In addition to system costs, solar energy imposes additional external costs. The costs of acquiring new customers for whom there are private net benefits of adopting solar energy remain quite high.

Further, there are costs to the electric grid operator for integrating the intermittent generation of solar energy (Hirth et al., 2015). On the other hand, there may be additional benefits for adopting solar energy to the grid operator due to the distributed nature of solar generation (Kaundinya et al., 2009).

Finally, solar energy has no direct air pollution or greenhouse gas emissions and therefore reduces pollution levels when solar energy replaces conventional generation. Deploying solar energy is seen as a key strategy as part of a transition to a more sustainable global energy system.

### **2.1. Compensating solar energy generation with net metering**

Compensation for electricity generation from solar energy depends on two general classes of factors: the opportunity cost of reducing electricity purchases from a utility and the payments received from a utility purchasing the electricity. In other words, the incentive to adopt solar energy varies based on the default electricity price consumers pay and the payment consumers (now generators of electricity) receive for selling electricity back to the grid.

One key policy to compensate solar energy producers is net energy metering (NEM). NEM is a policy adopted (in some form) by 47 states (DSIRE, 2013) that effectively compensates owners of solar energy generators. NEM works by effectively "running the meter backwards" such that electricity bills reflect only the electricity

consumed net of electricity generated. In effect, NEM allows customers to pay an electric bill for only their consumption net of their own solar generation. States with NEM often also include bill charges for fixed charges, which are meant to compensate the utility for their backup capacity and distribution infrastructure<sup>2</sup>.

NEM increases the benefits for distributed generation relative to utility-owned solar generation. NEM effectively compensates solar generation at the retail rate of electricity. Solar energy owned by utilities and sold in markets is sold in wholesale markets and is therefore compensated at the (much lower) wholesale rate.

Net metering policies vary in their design. Some states have adopted a real-time approach to net metering where electricity generation is compensated in relation to the real-time electricity prices (typically electricity prices are significantly higher during period of peak demand, such as the middle of a hot day).

The opportunity cost of avoided electricity consumption also varies by the rate structure set by states for different types of consumers. For example, large industrial electricity consumers typically face prices closer to wholesale prices, lowering the opportunity cost of adopting distributed generation. As another example, some states, like California, have adopted tiered pricing schedules (where the marginal price of electricity increases in consumption). This scheme increases the incentive for large electricity consumers to adopt distributed generation.

## **2.2. The value of solar**

The previous section described the variety of designs for compensation schemes for distributed generation based on variants of NEM. Conceptually, NEM compensated customers for their own avoided costs of purchasing electricity. Value of solar (VOS) provides an alternative conceptual basis for compensating distributed generation based on the net benefits provided back to the grid. NEM approaches and VOS approaches are likely to converge in perfect markets with competition, low transaction costs, fully internalized externalities, etc. Real-world electricity markets are far from this ideal, and there are therefore real differences in NEM and VOS rates.

VOS rates are calculated in bottom-up engineering studies of the different dimensions of benefits. The primary components of VOS are avoided costs associated with generation (fuel costs, capacity costs, operation and maintenance costs), avoided costs associated with transmission and distribution, and avoided environmental costs. (Taylor et al., 2015) Conceptually, VOS rates may also include locational benefits related to the particular grid-reliability benefits of distributed generation (Kaundinya et al., 2009).

VOS calculations are in their early stages. The first implementation of VOS concepts in actual rate setting was in the revised rate structure for Minnesota's community solar gardens in Xcel Energy's territory, beginning January 1, 2017.

## **3. Financing Solar Energy**

Deploying solar energy is likely to be a critical strategy in the transition to more sustainable urban and regional energy systems. A key challenge in accelerating the adoption of solar energy is developing financing models that can support the high up-front capital costs of purchasing and installing solar panels. Innovation in "finance and business solutions to expand access to capital" is a major focus of public policies to address the non-hardware costs of installing solar power (U.S. Department of Energy, n.d.).

## **4. Understanding the Solar Adoption Decision**

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<sup>2</sup> In states with increasing rate structures, NEM may provide a greater benefit than in states with flat rate structures if produced energy is accounted for equivalently to consumed energy. This is the case in California for residential solar consumers (Borenstein, 2015).

Electric utilities supply energy to consumers: this is the basic premise of the electric grid since it was constructed. But in recent history, distributed power systems such as rooftop solar are physically, economically, and socially evolving this century-old power delivery system into a flexible, two-way grid where consumers can choose to produce and consume their own energy.

Despite for the means for actors other than the electric utility to produce energy, political power dynamics embodied in grid actor characteristics such as NIMBYism and electric utility financial needs have discouraged sustainable levels of renewable energy development (Funkhouser et al., 2015; Wüstenhagen et al., 2007). Recognizing this, countries such as Germany have initiated customer participation and community ownership policies, making community energy projects a cornerstone of their climate policies (Kalkbrenner and Roosen, 2016).

As coevolutionary frameworks suggest that technological transitions are acted through multi-level interactions from social and political transformations, as well as financial and technological ones, citizen engagement becomes a key link in niche-level technology uptake (Foxon, 2011; Kallis and Norgaard, 2009; Warren and McFadyen, 2010; Wolsink, 2007). In this framework, citizen engagement and small-scale solar development rises from the niche level, affecting and affected by complex energy regimes above.

Currently, social networks, psychological perceptions, and socioeconomic characteristics are understood to be correlated with different levels of distributed solar photovoltaic uptake (Bauner and Crago, 2015; Bollinger and Gillingham, 2012; Dharshing, 2017; Rai et al., 2016; Wolske et al., 2017; Zhang et al., 2016). The uptake levels can be increased by proximity to other solar arrays, financial incentives that decrease uncertainty about the investment returns from the solar array, and pro-social or -environmental attitudes that diffuse within community organizations and geographic areas (Noll et al., 2014).

Broken down by type of customer and solar array, it becomes clearer that different subgroups of utility customers till uptake different types of solar photovoltaic technologies at different rates. Different corporate cultures lead to decisions to own or lease solar panels on their buildings (Hoffman and High-Pippert, 2014). Evidence from residential solar adoption in California, suggest that adopting customers are disproportionately wealthy, despite this effect declining in the last few years (Bornhoft, 2017). The California experience also indicates that there is little evidence that third-party ownership has been disproportionately utilized by low-income customers, despite the less restrictive financing constraints that third-party ownership affords. A number of state regulatory commissions have judged that solar programs, perceived as benefiting mainly wealthier customers, must try to provide equal access to customers without adequate roofs or credit scores (Funkhouser et al., 2015).

One survey also showed that potential solar customers also differed in their sensitivities between rooftop and community solar, with those who preferred community solar appearing more sensitive to price (Smart Electric Power Alliance, 2016). Community solar customers were further shown to prefer community solar models that were different from current offerings: less upfront cost, shorter contract terms, on-bill financing, and local location were all given preferences.

Concern over utility customer equity has rolled into community solar programs, whose customers appear again different from other solar consumers. Early surveys show that while very few are aware of community solar, potential customers (or in this case, subscribers) show that showings of trust and local pride, combined with a perceived financial and environmental benefit, could be enough to move an individual toward community solar adoption (Hoffman and High-Pippert, 2014; Smart Electric Power Alliance, 2016).

## **5. Xcel's Minnesota Community Solar Garden Program**

The statute which created community solar in Minnesota Xcel takes up only two pages. Adopted May 15, 2015, its language contains features which contain the essential players, goals, and puzzles of the policy (Bergan, 2014). First and foremost, the statute establishes the scope of community solar. The legislature directed Xcel Energy to

create a plan to operate community solar gardens by September 30, 2013 at the latest, and gave the Minnesota Public Utilities Commission (MNPUC) power to approve their plan for public use (State of Minnesota, n.d.). The final set of players relevant in the community solar garden scene in Minnesota are the developers of the solar gardens, which could be Xcel Energy or any other organization.

The goals of the community solar program are also established in the statute. Xcel's plan for community solar in Minnesota must:

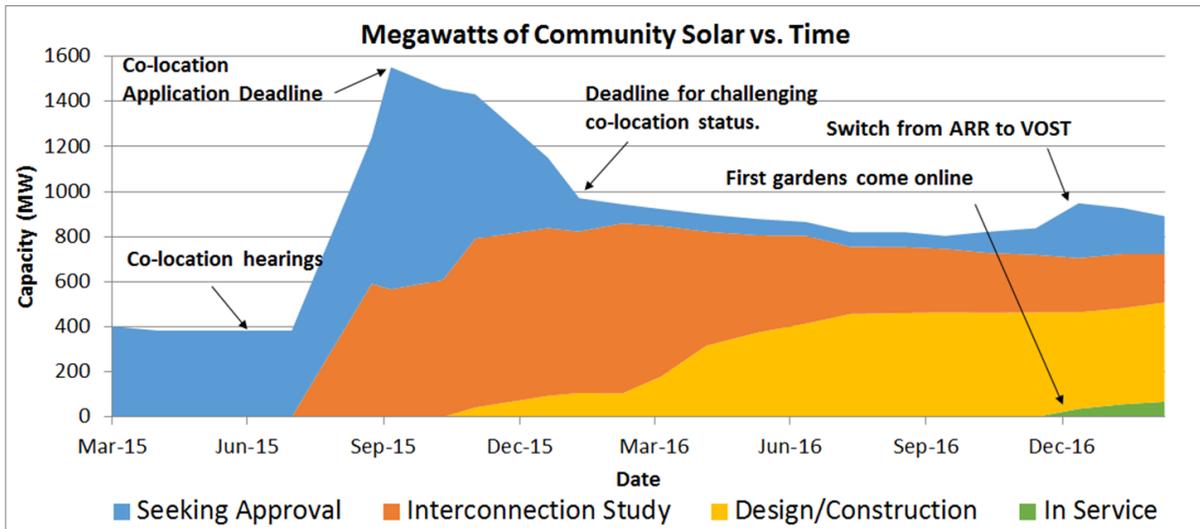
- “Reasonably allow for the creation, financing, and accessibility of community solar gardens;”
- “Establish uniform standards, fees, and processes for the interconnection of community solar facilities ...”
- “Not apply different standards to utility and nonutility community solar garden facilities;”
- “Be consistent with the public interest” (State of Minnesota, n.d.).

Together, these goals directed Xcel to build an ecosystem for solar which offered subscribers within its area the ability to subscribe to community solar gardens, and which gave other electricity developers an equal footing to generate power to be connected to Xcel's grid. These goals set a general direction for community solar, while allowing the utility to define a program that met its internal goals for power consistency and increases to grid capacity. However, the leeway allowed by the general language of these goals also allowed room for disputes between Xcel and MNPUC over the correct interpretation of the statute.

Xcel had established a framework for the program by, but due to an overwhelming number of applications (over 1GW by September, 2015), but it did not approve any sites for construction immediately. While HF 729 was enacted on May 21, 2013, implementation of the policy began in September of that year when Xcel filed their plan for the program (State of Minnesota, n.d.). The PUC required Xcel to begin crediting subscribers for their solar subscription within 180 days of MNPUC approval of their plan (State of Minnesota, n.d.).

MNPUC approved Xcel's plan for community solar gardens on August 7, 2014 (Bergan, 2014), and applications poured in quickly. The statute indicated that “There shall be no limitation on the number or cumulative generating capacity of community solar garden facilities,” but also indicated that “[each] solar garden must have a nameplate capacity of no more than one megawatt” (State of Minnesota, n.d.).

Solar garden developers and Xcel disagreed on the interpretation of these policy elements. Some developers assumed that they could co-locate as many 1MW solar gardens on the same plot of land as they wanted, bypassing the cap written into the policy, and filed applications accordingly. Xcel argued that the legislation was clear in the way it capped the capacity of any site at 1MW (citation needed). In June 2015, MNPUC ruled that applications submitted by September 25 of that year could co-locate up to 5MW on the same site, and that subsequent applications would be limited to 1MW on each site (Vine, 1997). This decision was followed by a rapid spike in application submissions prior to the September deadline, as well as an increase in the number of withdrawn applications. See Figure 5 for a graphical representation of applications and key decisions.



**Figure 5.** Community solar project proposals and development pipeline in Xcel’s Minnesota program with key policy developments noted (original figure).

More recently, Xcel and MNPUC have implemented a change from the adjusted retail rate (ARR) for community solar to the value of solar (VOS) rate. This VOS rate pays subscribers less for the output of their panel, but includes adders that break down the gains and losses of a new panel based on its location, the sort of fuel it offsets, and why it is valuable to the utility.

The statute establishing the community solar garden program called upon Xcel to “reasonably allow for ... accessibility of community solar gardens” and to make a plan “consistent with the public interest” (State of Minnesota, n.d.). The lack of new applications in the three months since the implementation of the VOS tariff on January 1, 2017, might indicate that developers have not found a way to make this new structure produce the same benefits that drew them to the program in previous years (White, 2017).

While the political rhetoric around the initial development of the Xcel community solar program had suggested that the program would be developed to prioritize residential subscriptions, the first 59 MW of project development was dominated by commercial, not residential, subscribers. While 62% of subscribers in this initial batch were residential electricity customers, they represented only 13% of total subscribed solar capacity. This implies that the average commercial subscriber, subscribed to over 10-times the capacity of the average residential subscriber.

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